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I.

An account of the Magnetic Observations made at the Observatory of Harvard University, Cambridge.

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THE object of this communication is to give some information in regard to the nature and progress of the series of magnetic observations which has been instituted at the Observatory of Harvard University in coöperation with the plan of the Royal Society, as

* The authors of this paper desire it to be understood that Professor Benjamin Peirce has rendered great assistance in conducting the observations on Term and other days, and in devising simple methods of reduction. The empirical curves which are mentioned in this paper and which were calculated at a great cost of time and labor are the voluntary contribution of this gentleman to the objects of the Observatory.

detailed in their Reports.* Regular magnetic observations were undertaken at Cambridge in March, 1840, being confined at first to the monthly Term-days of the English scheme. The meteorological observations recommended in the same Reports were also begun in a modified form, adapted to the resources of the Observatory, at that time; but it is not proposed to speak of them except so far as they may be connected with the remarks on Terrestrial Magnetism. The necessity of conforming, as near as possible, to the general plan and acting in concert is apparent, as the observations are intended rather for comparison than for independent use. But in the execution of this charge, as far as it has yet progressed, questions of curiosity or of higher interest have been constantly occurring which suggested the expediency of observations additional to, but not interfering with, the chief work. In some cases, these inquiries could be answered or the approximate data for a solution be derived from the means at our command; but often, they depended upon comparisons between elements simultaneously observed at different places. In the latter instances, we have had valuable assistance in the prompt coöperation of Lieutenant C. J. B. Riddell at the Magnetic Observatory in Toronto, U. C. The results of these extraordinary observations will be exhibited in their proper place. That an opportunity may be afforded of judging of the degree of accuracy of the observations we shall first give a description of the plan of the Observatory, the nature, position and adjustment of the instruments, and the method of making the observations.

Plate I. is a ground plan of the University Observatory. The

* Royal Society. Report of the Committee of Physics, including Meteorology, on the Objects of Scientific inquiry in those sciences. London, 1840.

Report upon a letter addressed by M. Le Baron de Humboldt to his Royal Highness the President of the Royal Society, and communicated by his Royal Highness to the Council 9th June, 1836.

projections are given of only those parts of the building which are devoted to the purposes of an observatory; they were built expressly for this object and are attached to the northwest and southwest corners of the house in which the observers reside; one room of this house which is used for an observer's room is represented in the plate by *K.* *A* is the projection of the dome erected on the top of the house, and the rectangle is the opening through the floor by which it is entered. This dome has a revolving roof of panel work and plate glass with a vertical section which can be brought into any azimuth required by the observation. *E* is the place of the astronomical clock.* It has been thought inexpedient to carry the clock into the transit room where it would be exposed to great changes of temperature. For this and other reasons it is kept in a fixed position in a room where the temperature is nearly uniform throughout the day and night, and at all seasons. The observations are made directly with a chronometer which is compared with the clock as often as is necessary. This practice has recommended itself from long trial as convenient and safe. *G* represents the place of the barometers. The observatory is liberally furnished in this respect, having one standard barometer by Cary and two barometers by W. & S. Jones. Besides these, a beautiful standard barometer made by I. Newman has just been received and has been placed between the windows on the south side of the same room. As this barometer is after the model of those used at the other magnetic stations and has been compared directly with the standard barometer of the Royal Society which was made by the same artist on the same principle, it may be regarded as the best standard in this country. The following are the results of the comparison:

Royal Society Standard	29.506 in.	Royal Society Standard	28.604 in.
Cambridge Standard	29.504	Cambridge Standard	28.600

* This clock was made by Parkinson and Frodsham.

Newman's barometers are superior in several respects to all others. The graduated scale which measures the height of the mercury is made of brass, and slides by means of a tangent screw so that its end, which is of ivory, can be made to touch the upper surface of the mercury in the cistern. This is known to be the case when the reflected and actual point are in contact. The tube which holds the mercury is 0.512 of an inch in diameter; therefore the effect of capillary attraction is inappreciable.* The Royal Society have published in their Report a table of corrections for temperature, calculated by Professor Schumacher and applicable to this kind of barometers, by which an allowance is made for the unequal expansion of the scale and the mercury corresponding to every degree from 32° of Fahrenheit and for every half inch of the barometer. The vernier of Newman's standard barometer reads off to $\frac{1}{500}$ of an inch.

The piers which support the transit instrument are situated at *B*, and may be better understood from *m n o* in another part of the plate. The piers are $9\frac{1}{2}$ feet long, with a tripod base; *m* is the east and west view, and *n* the north and south view; *o* is a granite pedestal, 6 feet long, $5\frac{1}{2}$ feet wide, 2 feet 10 inches deep, firmly resting upon a gravel foundation. The lower side of this block of granite is $7\frac{1}{3}$ feet below the floor. The sides of the transit room are supported on independent walls, separated from the base of the transit by a trench 3 feet wide which has been filled up with tan to preserve the stones from being deranged by frost. Care has been taken not to allow the floor to press upon the piers where they enter it. By these precautions the instrument is protected from the jar of footsteps in the observatory and the disturbances of carriages. An excellent Transit-instrument, made by Troughton and Simms, 4 feet long, was placed in adjustment in January, 1840, and a series of meridian observations, including moon-culminating stars, has been

* This correction for a tube whose diameter is 0.5 inch is only 0.003 inch.

continued from that time, which by their comparison afford satisfactory evidence of the stability of the pillars on which the instrument rests. *F F* is the direction of the astronomical meridian and intersects Blue Hill, in Milton, west of its summit. A firm and substantial meridian mark has been erected on that hill, consisting of a tower of round and substantial masonry, thirteen feet in diameter at the base, seventeen feet high above the ground and nine feet in diameter at the top. On this is placed a mark seven feet high, of the shape of the rhomb, with its larger axis perpendicular to the horizon. By this means the central vertical wire of the Transit instrument is put in the meridian. It appears from Mr. Borden's State Survey that the distance between the mark and the instrument is 58,520.5 feet. A brick house on the meridian line, about a mile from the Transit-instrument, affords a convenient though less accurate reference, when the state of the atmosphere does not allow the distant mark to be distinctly seen.

A short abstract from the astronomical records of the Observatory is annexed, to show the state of the Transit-instrument and the confidence that may be reposed in the accuracy of the time used in the magnetic observations. The equatorial intervals of the wires of the Transit-instrument, as deduced from a large number of observations, are thus:

	s.
From 1st wire to the mid-wire .	33.96
From mid-wire to 5th . . .	33.94
From 2d to mid-wire . . .	16.88
From mid-wire to 4th . . .	16.86

The following extract from the Transit-book includes all the standard stars whose transits were observed from July 10th to July 25th, 1840. In a few cases, an observation has been rejected because one of the five wires was accidentally missed. The introduction of such stars would vitiate the general comparison.

No.	Date. 1840.	Name of Star.	Declination of Star.	Obs'd time of transit by the sidereal clock.	Right Ascension of Star.	Clock slow of sidereal time.	Difference of obs'd times—Diff. of AR.*
	July.		° ′	h. m. s.	h. m. s.	m. s.	s.
1	10	Polaris S. P.	+88 27	13 00 57.39			
2	"	α Virginis	−10 20	13 15 38.84	48.56	− 1 9.72	
3	"	ε Bootis	+27 45	14 36 53.14	2.64	− 1 9.50	+ 0.29
4	"	α2 Libræ	−15 23	14 40 55.50	5.10	− 1 9.60	− 0.10
5	"	β Libræ	− 8 48	15 7 17.60	27.19	− 1 9.59	+ 0.03
6	"	α Cor. Bor.	+27 15	15 26 48.02	57.68	− 1 9.66	− 0.05
7	"	α Serpentis	+ 6 56	15 35 16.84	26.37	− 1 9.53	+ 0.14
8	"	β1 Scorpii	−19 22	15 55 02.48	11.90	− 1 9.42	+ 0.13
9	"	δ Ophiuchi	− 3 17	16 3 51.52	61.19	− 1 9.67	− 0.25
10	"	Antares	−26 4	16 18 30.42	40.10	− 1 9.68	− 0.00
11	"	τ Scorpii	−27 52	16 24 49.92	59.72	− 1 9.80	− 0.11
12	"	α Herculis	+14 35	17 6 14.86	24.47	− 1 9.61	+ .22
13	"	γ Draconis	+51 31	17 51 46.94	56.63	− 1 9.69	− 0.05
14	"	Polaris	+88 27	1 0 59.80			
15	11	α2 Libræ	−15 23	14 40 53.87	5.09	− 1 11.22	
16	"	β Ursæ Minoris	+74 48	14 50 06.59	18.27	− 1 11.68	− 0.46
17	"	β Libræ	− 8 48	15 7 16.05	27.18	− 1 11.13	+ 0.56
18	"	α Serpentis	+ 6 56	15 35 15.03	26.36	− 1 11.33	− 0.18
19	"	β1 Scorpii	−19 22	15 55 0.59	11.90	− 1 11.31	+ 0.03
20	"	δ Ophiuchi	− 3 17	16 4 49.95	61.18	− 1 11.23	+ 0.08
21	"	Antares	−26 4	16 18 28.67	40.10	− 1 11.43	− 0.19
22	"	τ Scorpii	+14 35	16 24 48.41	59.72	− 1 11.31	+ 0 12
23	"	α Herculis	+12 41	17 7 13.09	24.46	− 1 11.37	− 0.03
24	"	α Ophiuchi	−27 52	17 25 22.45	33.80	− 1 11.35	+ 0.03
25	"	γ Draconis	+51 31	17 51 45.11	56.62	− 1 11.51	− 0.14
26	12	β Libræ	− 8 48	15 7 14.90	27.18	− 1 12·28	
27	"	α Serpentis	+ 6 56	15 35 14.06	26.36	− 1 12·30	− 0.00
28	"	β1 Scorpii	−19 22	15 54 59.52	11.89	− 1 12·37	− 0.06
29	"	δ Ophiuchi	− 3 17	16 4 48 98	61.18	− 1 12·20	+ 0.18
30	"	Antares	−26 4	16 18 27.88	40.09	− 1 12·21	− 0.00
31	"	α Hercules	+14 35	17 6 12 02	24.46	− 1 12·44	− 0.20
32	"	Sagittarii	−30 14	17 47 40.84	53.07	− 1 12·23	+ 0.24
33	"	Vega	+38 38	18 30 22.04	34.37	− 1 12.33	− 0.06
34	"	φ Sagittarii	−27 09	18 34 31.52	43.76	− 1 12.24	+ 0.09
35	14	α Herculis	+14 35	17 6 10.16	24.45	− 1 14.29	
36	"	α Ophiuchi	+12 41	17 26 19.76	33.79	− 1 14.03	+ 0.27
37	"	μ Sagittarii	−21 6	18 3 01.46	15.67	− 1 14 21	− 0.16
38	"	α Lyræ	+38 38	18 30 20.12	34.37	− 1 14.25	− 0.02
39	"	β Lyræ	+33 11	18 43 59 16	13.55	− 1 14.39	− 0.13
40	"	ζ Aquilæ	+13 38	18 56 52.48	6.72	− 1 14.24	+ 0.16
41	"	δ Aquilæ	+ 2 48	19 16 14.08	29.30	− 1 14.22	+ 0.04
42	"	α Aquilæ	+ 8 27	19 41 47.82	61.98	− 1 14.16	+ 0.07
43	"	β Aquilæ	+ 6 01	19 46 16.58	30.66	− 1 14.08	+ 0.08
44	"	α2 Capricorni	−13 2	20 7 59.79	14.11	− 1 14.32	− 0.23
45	"	α Cygni	+44 43	20 34 47.44	61.75	− 1 14.31	+ 0.03
46	"	61 Cygni	+37 58	20 58 32.94	47.03	− 1 14.09	+ 0.24
47	"	ζ Cygni	+29 35	21 4 56.42	10.86	− 1 14.44	− 0.35
48	"	α Cephei	+61 55	21 13 34.03	48.06	− 1 14.03	+ 0.42
49	"	β Aquarii	− 6 16	21 21 56.99	11.42	− 1 14.43	− 0.39
	"	Polaris 1st wire		0 40 3.80			
	"	" 2d "		0 50 36.20			
	"	" mid "	+88 27	1 00 59.50			
	"	" 4th "		1 11 22.70			
	"	" 5th "		1 21 55.40			
50	"	Mean		1 0 50.50			
51	15	Polaris S. P.	+88 27	13 0 58.40			
52	"	Arcturus	+20 01	14 7 9.06	24.37	− 1 15.31	
53	"	β Libræ	− 8 48	15 07 11.74	27.15	− 1 15.41	− 0.05
54	"	α Cor. Bor.	+27 15	15 26 42.52	57 62	− 1 15.10	+ 0.32
55	"	α Serpentis	+ 6 56	15 35 11.06	26.33	− 1 15 27	− 0.16
56	"	β1 Scorpii	−19 22	15 54 56.48	11.87	− 1 15.39	− 0.11
57	"	η Draconis	+61 53	16 20 37.80	53.08	− 1 15.28	+ 0.13
58	"	α Herculis	+14 35	17 6 9.54	24.75	− 1 15 21	+ 0.11
59	"	olaris	+88 27	1 0 56.40			
					The mid-wire bisecting the mark on the Bluehill.		
60	25	Polaris S. P .	+88 27	13 0 47.50			
61	"	Arcturus	+20 01	14 6 54.82	24.25	− 1 29.43	
62	"	α Cor. Bor.	+27 15	15 26 28.06	57.50	− 1 29.44	− 0.00
63	"	α Serpentis	+ 6 56	15 34 56.60	26.14	− 1 29.54	− 0.09

* This difference has been corrected for the error of the clock. This error is found from the 7th column of the Table and may be seen on page 7.

Abundant materials are furnished by the preceding catalogue of transits for deducing the state of the instrument, the direction of the meridian and the true sidereal time. By means of these observations the rate of the clock is found to be

	s.		s.
From the 10th to 15th July	—1.16	From 15th to 25th July	—1.41
	—1.09		—1.43
	—1.15		—1.43
	—1.17		
	—1.12		—4.27
	—5.69	Mean	—1.42
Mean	—1.14		
	—1.42		
	—2.56		
	—1.28	Mean from 10th to 25th July.	

There are three methods in common use for determining the azimuth of the Transit instrument. One of them employs the successive intervals between the upper and lower passage of Polaris; another compares the transits of two circumpolar stars whose right ascensions vary about 12 hours; while the last depends upon the transits of high and low stars, including north and south stars. When the latter method is adopted, it is advisable to select stars whose difference of declination is at least equal to 40°. There are defects in all these methods. The first supposes the rate of the clock to be uniform during the 24 hours; this may not always be the case; but on account of the slow motion of the star a considerable error in time would make but a small difference in the azimuth of the instrument. The second process depends upon the

clock for a much shorter time; but it requires four observations and the accidental error of these may exceed that produced in the first case by the clock. Lastly, the third mode requires only two observations and depends on the clock only for a short time; but it supposes the Tabular place of the star to be accurately known. A careful determination of the meridian must be based upon a combination of the three methods; when this is done, the instrument is adjusted with great exactness. This reduction has been made out of the transits in the table, and the azimuth of the instrument when on the meridian mark, calculated from 18 different sets of stars selected according to the known conditions of the problem, gives as a mean result

0″.072 west of south, being the azimuth of the south end of the Transit instrument.

The three successive transits of Polaris observed on the 14th and 15th July give

0″.11 west of south.

The final mean is 0″.091 west of south.

The octagon apartments to the west of the Transit-instrument contain a Gauss Magnetometer by which changes of magnetic declination are observed. They are built of wood, with copper and zinc nails; the walls rest on wooden posts; iron, stone and all other substances known or suspected to exert magnetic influence having been carefully excluded from every part of the building. *F D* is the direction of the astronomical meridian and *D C* of the mean magnetic meridian. The three circles at *D* are the projections of so many wooden posts which are bound firmly together at the top and support the marble table on which a Variation-transit is placed. This instrument was made by Troughton and Simms, and is used in the magnetic observations. The larger interior circle represents

the table; the chord at right angles to the magnetic meridian is the projection of the scale which is read in the observations; *C* is a Gauss Magnetometer which is fitted up after the style of those at the Gottingen Observatory. The three circles at *C* are the feet of three posts, ten feet long, which unite at the top eight feet above the floor and give a stable point of suspension to the needle. The rectangle, enclosed within the feet, is the box which surrounds the magnet and protects it from currents of air. Within the box may be seen this magnetized bar in the magnetic meridian, with a mirror firmly fixed to its south end to reflect the scale at *D* into the tube of the Variation-Transit. The bar is suspended by a copper wire silvered, 0.011 of an inch in diameter, 5 feet 6 inches long, and with its fixtures weighs about 3 pounds.

From this arrangement it follows, that as the bar varies in its position it must carry the mirror with it. The place of the mirror determines the mark on the scale which is reflected into the centre of the telescope; so that as the reflecting surface moves the marks of the scale that are successively seen are read off and employed to ascertain the motions of the bar. The scale at Cambridge is so divided that the angular motion of the needle is read directly from it without any reduction. This novel mode of observing changes of magnetic Declination is a great refinement upon the old methods, and has given an accuracy to the determination of this magnetic element which has hitherto been considered attainable only in astronomy. For a more minute description of the Gauss instruments and the directions to be obeyed in observing with them, the reader is referred to Taylor's Scientific Memoirs, Parts V. and VI. It is necessary to omit in this place any further details except such as are required in order to understand the remarks which follow. As all the observations embraced in this paper were made

with the Gauss Magnetometer, I shall pass at once to them and leave the description of the rest of the buildings and the instruments placed in them for the close.

The plan of magnetic observations, recommended by the Royal Society and generally adopted at the magnetic Observatories, prescribes that the Declination Magnetometer, and the Horizontal and Vertical Force instruments, shall each be observed once every two hours during the 24 hours on every day of the year; that is to say, one of them is read $2^m\ 30^s$ before each even hour; one at the even hour, and the third $2^m\ 30^s$ after the even hour. One day in each month has been set apart for observations of the three instruments *at shorter intervals.* On these days, which are called Term-days, the Declination Magnetometer is observed every five minutes, and the other instruments every 10 minutes, making four separate observations every 10 minutes, or 576 in the day. A short description of the instruments by which these observations are made is promised at the end of the paper. They have but recently been received and adjusted, and regular observations were made for the first time with them on the Term-day of March, 1841.

The observations with the Gauss Magnetometer, which make the subject of this article, have been coincident in time with those taken with the Declination Magnetometer at the British stations and are therefore comparable with them. The Report of the Royal Society on this great Magnetic Adventure provides that the observations shall be made as closely as the nature of the instruments, with all the recent refinements of mechanical skill added to the ingenious artifices of the observer, will permit; and the time is to be carefully noted after having been determined by the assistance of astronomical instruments, so as to make the observations at the different stations in a practical sense simultaneous. Observations, according

to this rigid system, were originally expected to extend over three years. When the materials thus patiently gathered from so many remote sources shall be collected, they will pass into the hands of competent persons to furnish the elements for a complete Theory of the earth's Magnetism; and any attempt to pronounce at this time positively on this great subject would justly be regarded as premature. But it is equally certain that there are secondary questions, of considerable intrinsic importance, which may be discussed now as well as at any time; the settlement of which will be facilitated by an occasional publication of portions of the regular magnetic observations. Much light may be thrown upon the general subject by a comparison of partial results; and parts of a well-concerted plan to which no present objection appears may prove useless in fact, and be either remodelled or superseded by other observations which experience has shown will serve a better purpose. Moreover, the subject of Terrestrial Magnetism deeply engages the attention of the scientific world, and many not actively engaged in the research will be anxious to understand the progress of a scheme which promises to shed light upon this complex problem. In this great country it is highly important that something should be done to awaken the attention of individuals and of the American nation; and to bespeak their bounty in favor of a scientific enterprise which has received the highest patronage of European and other governments. The commercial prosperity no less than the interests of pure science will be affected by the spirit and liberality with which this bold project is sustained and conducted. It is hoped that the present publication may not prove useless for some of these purposes. A writer in the "London Quarterly Review," after speaking of the materials that will be collected at head-quarters, by three years' contribution, proceeds thus: "Voluminous beyond all former precedent as the

mass of data thus accumulated must of necessity be, we trust the whole will be printed (each nation and each department of course providing for the publication of its own). No consideration of economy should be allowed to interfere with the performance of this necessary duty, without which we look upon all that shall be done as virtually thrown away. Highly as we respect the illustrious body above mentioned, and applaud their selection of the individual into whose hands the results will in the first instance pass; yet their full, fair, and effectual discussion can be secured by no other means than by inviting to it the collective reason of the age, and of all succeeding ones, and affording every one who may think proper to engage in the task, now or hereafter, ample opportunity to do so."*

It should be stated, for the information of those who have not watched the progress of the recent investigation into the laws of the earth's Magnetism, that it originated with Baron Humboldt and Professor Gauss of Gottingen. In 1828, Baron Humboldt laid the foundation of the German Magnetic Association, by erecting a magnetic Observatory at Berlin, which was imitated in various parts of Germany and Russia. In 1833, the attention of Gauss was called to the theoretical consideration of the earth's Magnetism, but he found himself soon arrested by the want of accurate and extensive data. He instituted accordingly a magnetic Observatory at Gottingen, and having furnished it with new instruments began observing in March, 1834. Coöperation was sought and obtained in various parts of the continent; a more intimate alliance was formed between the several points of observation; and after various modifications in the time and mode of observing, the amount of which was to make the observations more minute and the number of Terms smaller, one day in the months of February, May, August and No-

* *London Quarterly Review*, No. cxxxi, page 303.

vember was selected, in which observations were to be made at every five minutes during the 24 hours. These are the present German Magnetic Term-days. In this advanced stage of the research, Humboldt addressed a letter to the President and Council of the Royal Society, soliciting the countenance and support of the British nation; and this appeal, after having been met in the most prompt and generous manner at home, was sent abroad to various Academies and men of science in this country. The extent and important magnetic position of America were insisted upon in the appeal sent out to it, and it is to be wished that the example set by the magnetic Observatory in Philadelphia, under the care of Professor Bache, and by the American Academy of Arts and Sciences in Boston who have supplied the Cambridge Observatory with the requisite instruments, will be a motive to our government and to individuals to take measures in this matter worthy of their wealth and energy, as well as the eminent local advantages which they enjoy in regard to this scientific investigation.

The following table, from page 38 of the Report of the Royal Society, is published here for the information of those who have not seen the original.

Days of Commencement of the Terms of simultaneous observation, during the years 1840, 1841, *and* 1842.

Month.	1840.		1841.		1842.	
January . . .	Wednesday	22	Wednesday	20	Wednesday	19
February . .	Friday	28	Friday	26	Friday	25
March	Wednesday	18	Wednesday	24	Wednesday	23
April	Wednesday	22	Wednesday	21	Wednesday	20
May	Friday	29	Friday	28	Friday	27
June	Wednesday	24	Wednesday	23	Wednesday	22
July	Wednesday	22	Wednesday	21	Wednesday	20
August . . .	Friday	28	Friday	27	Friday	26
September . .	Wednesday	23	Wednesday	22	Wednesday	21
October . . .	Wednesday	21	Wednesday	20	Wednesday	19
November . . .	Friday	27	Friday	26	Friday	25
December . .	Wednesday	23	Wednesday	22	Wednesday	21

The observations on the Term-days with the Gauss Magnetometer were begun at the Cambridge Observatory in March, 1840, and no one has been omitted since that time.* The curves for only two of these days, the 29th of May and the 21st of October, are published; but the numbers which express the mean results for every five minutes during the 24 hours on all the Term-days are placed in Table I, at the end of the Paper. This mode is preferable in some respects to publishing the curves, as it enables any one who intends to make a comparison, to draw a curve for Cambridge on the scale used in observations made at other places. In our observations, the time was obtained accurately from the Transit-instrument and astronomical clock; and the scale which was reflected from the mirror at the southern extremity of the bar, and read off by the Variation-Transit, easily allowed of being marked to $\frac{1}{8}$ of a minute. The experience of the observers has satisfied them that dependence may be placed upon each separate reading within that limit of error. But other considerations make it necessary to determine the position of the Magnetometer for any assigned time by more than a single reading. As the bar in passing from one angle of declination to another is maintained always in a vibratory state, it is necessary to eliminate what is due to the oscillation from what belongs to an absolute change of declination. If the arc of vibration were constant, it would be eliminated by observing the limits of excursion of the magnetized bar and taking the mean between them. But the natural tendency of the

* As the Report of the Royal Society containing the details of their plan had not been received when the observations commenced, two of the Term-days were incorrectly taken, and the observations in April, besides being undertaken on the wrong day, were so imperfect that they have been left out of the account entirely. Instead of March 18, March 27, and instead of July 22, July 24 were observed at Cambridge. This must be considered in the comparison of these days with observations made elsewhere.

arc of vibration is to become shorter for every new excursion, and if the arc be of considerable length this circumstance must be taken into account. As the decrease of arc must be nearly uniform for a few vibrations, this is done by noting the limits of three successive excursions, and the mean of two means thus obtained is the true position of the bar for the middle time. Thus, if a, b, c are the readings, $\frac{1}{2}$ ($\frac{1}{2}$ (a+b)+$\frac{1}{2}$ (b+c)) or $\frac{1}{4}$ (a+2b+c) gives the place of the magnetic meridian for the time when b was observed. If the arc of vibration is very small, this correction will be inappreciable and the mean of two observations will suffice. But the declination itself meanwhile may vary by sudden and irregular movements, and then the process of observation and reduction becomes more intricate. Facts assure us that the magnetic meridian is subject to abrupt and lawless fluctuations as well as uniform and progressive variations. The practical mischief of these disturbed motions is diminished by the fact that they will most probably occur during periods of unusual perturbation; and although they must be kept in view when studying the laws of remarkable derangements of magnetic influence, their effect will be insensible in the regular and periodic changes.

A greater difficulty that affects particularly simultaneous observations is this. The precise moment of time to which the mean result corresponds may not be that for which the declination is sought; and the interpolation of the required times between the observed times is a matter of troublesome and uncertain calculation. This labor is prevented by an ingenious device of Gauss, in the way of observing. If two observations of a bar are made at an interval equal to the time of one vibration, the mean is the place for the intermediate moment. This is a proposition mathematically exact, if the change of declination can be regarded as uniform and the arc of vibration constant. It will, therefore, be practically true

whenever no remarkable disturbances are apprehended and the arc of vibration is small; or within the same limitations as the other methods. If now the position of the magnetic meridian is desired for any definite moment, the first observation is made to precede this period by half the time of the bar's vibration, and the second to follow the period at the same distance. Thus, if t be the time of vibration, and T the time of mean observation, the actual observation must be made at $T-\frac{1}{2}t$ and $T+\frac{1}{2}t$. For greater accuracy, the final result is made to depend on several partial results as will be seen by an illustration. The time of vibration of the Gauss Magnetometer used at Cambridge is about 54″. This is divided into as many parts as separate observations can be conveniently taken during that time. It has, therefore, been divided into 6 intervals of 9″ each, and a separate observation is made at each interval. This is done during two vibrations of the needle, or 1′ 48″. By taking the mean of every two observations which have an interval of 54″ we have a partial result for the middle time, and these partial results are combined so as to give a final result for any time when the declination is required. If this time is 2^h 5′ the first observation is made at 2^h 4′ 6″, and repeated at intervals of 9″ till 2^h 5′ 54″. An example is given from the observations made June 26, at 0^h of Gottingen mean time.

H.	M.	S.	Readings of the Scale.	Partial Results.	Times corresponding to partial Results.	
23	59	6	108.750			
		15	9.000			
		24	9.500		h	
		33	110.000	109.312	23 59′ 33″	
		42	10.125	9.062	42	The Final Mean of the 7 partial results gives 109.294.
		51	10.000	9.250	51	
		0	9.875	9.375	00 0	
		9	9.125	9.312	9	
		18	9.000	9.375	18	
		27	8.750	9.375	27	
		36	8.500			
		45	8.750			
		54	108.875			
				Mean 109.294	0 0	

Thus it appears that each position of the needle is determined from 13 separate observations; and as each reading is to $\frac{1}{8}$ of a minute the mean of all may be considered as within a smaller error of observation, and only subject to the exception that the law of reduction is not rigorously exact when the change of declination during 1′ 48″ is not uniform. If the arc of vibration be so large as to have a sensible decrease the effect is cancelled when the readings extend through twice the time of vibration. On Term-days this process is repeated every 5′ during the 24 hours, so that 3,744 observations are made which give 288 mean positions. This was the rule of the Observatory till June 26th, 1840, when a slight modification was introduced which diminished the labor of observation and reduction without compromising the accuracy of the result. Thus the observation of June 26th, 3^h 40′, P. M.* which was the first one made in this way, stands thus; it should be remembered that the column of figures to the right of the point are not tenths but eighths.

H.	M.	S.	Readings of the Scale.	Partial Results.	Times corresponding to Partial Results.	
3	39	10	106.3			
		19	105.7			
		28	105.3			
		37	105.2	106.	39′ 37″	
		46	105.1	105.937	46	
		55	105.2	105.812	55	
		4	105.5	105.875	40 4	The Final Mean gives 105.854 as the number on the scale corresponding to the magnetic meridian at 3^h 39′ 59″.5.
		13	106.0	105.750	13	
		22	106.2	105.750	22	
		31	106.4			
		40	106.3			
		49	106.2			
Means.			105.854	105.854	39′ 59″.5	

By this method, which is the same in principle as the other, only 12 observations are made, and the mean of them is the same as the

* Gottingen Mean Time is to be understood wherever it is not otherwise stated.

mean of the partial results, so that the latter column in the table is unnecessary and a great part of the labor of reduction is saved. The number 12 is a convenient divisor, and after the whole minutes are found the decimals are taken out of a Table calculated for this purpose and embracing every case that can occur. Look in the vertical column at the right or left for the whole numbers of the remainder, after dividing by 12, and in the top or bottom line for the eights, and in the corresponding square is the decimal value of the remainder.

	0	1	2	3	4	5	6	7	
0	000	010	021	031	042	052	062	073	0
1	083	094	104	115	125	135	146	156	1
2	167	177	187	198	208	209	229	240	2
3	250	260	271	281	292	302	312	323	3
4	333	344	354	365	375	385	396	406	4
5	417	427	437	448	458	469	479	490	5
6	500	510	521	531	542	552	562	573	6
7	583	594	604	615	625	635	646	656	7
8	667	677	687	698	708	719	729	740	8
9	750	760	771	781	792	802	812	823	9
10	833	844	854	865	875	885	896	906	10
11	917	927	837	948	758	969	979	990	11
	0	1	2	3	4	5	6	7	

It must be observed that the mean result obtained above corresponds to $3^h\ 39''\ 59''.5$, and not $3^h\ 40'$. But the difference of half a second comes within the limits of unavoidable errors of observation and is of no weight in deciding on the comparative merits of the two methods each of which depends on a knowledge of the time of vibration of the bar. But this time changes slightly from one period to another, and although always assumed to be $54''$ it is strictly $53''.4$ on the average, and oscillates

about this mean value.* Whenever observations have been made with the Gauss Magnetometer since June 26th, 1840, it has been the rule of the Observatory, recommended by its superior simplicity and freedom from all practical objections, to take 12 readings at intervals of 9″, commencing 50″ before the real time, and to consider the mean of them as the final determination of position for that moment. Neither the Gauss method nor that of Cambridge which is based on it is practicable when the bar is agitated by unusual magnetic influences, as in seasons of violent disturbance, in consequence of the great extent of its motion. In such emergencies, the extreme of every excursion is recorded so long as this perturbation continues and an approximate time is obtained as exact as circumstances allow. The reduction is then made by this Formula $\frac{1}{4}(a+2b+c)$ which has been already explained. After the mean results for every five minutes during the 24 hours of a day are obtained by any of these processes, they are used as the data for projecting a diurnal curve of magnetic declination. Two lines are drawn upon a sheet of paper at right angles to each other and assumed as the axes of rectangular coördinates. One of them is divided into 24 equal intervals each of which is subdivided into smaller parts according to the scale of the chart. The other line is also divided in portions corresponding to degrees and minutes of arc. Any point that is most convenient may be selected as the origin of the coördinates, and by considering the time as ordinate and the result of observation annexed to it as abscissa we obtain as many points of a daily curve as there are mean results of observation. In ordinary Term-days the number is 288. When so many points are fixed upon the sheet they are connected by

* The mean of 28 vibrations in April was 53″.05; of 21 in July 53″.38; of 22 in September 53″.45; of 12 in October 53.65.

straight lines or curves of the simplest curvature. From the details published in regard to the principle of observing it may be inferred how closely these curves will represent the actual magnetic changes for the day. It cannot be denied that disturbances may happen, of less amount than the minimum quantity of observation or at less periods than 5′, which will elude the vigilance and refinements of the present state of Magnetic science. It has been noticed on more than one occasion that the bar has been instantaneously checked in the midst of a vibration and forced to retrace its steps by a long sweep in the opposite direction. The lines which are now drawn straight or in the most natural curve from one fixed point to another on the sheet might, if they were sensible of the shorter and more rapid magnetic impulses, change their curvature several times during the passage.

Plates II. III. IV. and V. represent the diurnal curves of magnetic declination for the days given on the plates; and we are first to consider from an attention to them as well as to the figures which describe the other days at the end of the communication whether the fact of a regular cycle of variations in the declination during the 24 hours is confirmed by these observations. The theory appears now to be well established, that the Elements of Terrestrial Magnetism are subject to daily, monthly, yearly, and secular perturbations similar to the periodical and secular variations which are known in astronomy. But in the astronomical problem, no derangement occurs whose cause is not looked for and generally found in the uniform operation of the simple law of gravity in its direct or reflected action upon the various members of the solar system. The singular fact of Encke's comet, which experiences a delay which has been attributed to a resisting medium, may be regarded as a solitary exception to the general truth. The laws of motion

among the heavenly bodies are so few and clear that the character of the disturbance will generally indicate something in regard to the cause which produces it. But the Elements of the Earth's Magnetism are exposed to abrupt and violent fluctuations, which, so far as the circumstances are known, acknowledge no periods and, although perhaps capable of being explained by many conceivable causes which are in constant operation and therefore at the disposal of the philosopher, they cannot be distinctly brought home to any single one and are at present regarded as inexplicable. These magnetic hurricanes, as they have been fancifully called, are often exhibited during Auroral appearances, but many of them, so far as has been observed, are not coincident in time with this or any other class of natural phenomena. Now, every observed position of the needle for a given moment is beset with all these regular and irregular variations; which must be carefully eliminated by multiplying the number and shifting the exposure of the observations before we can be assured what is the exact and absolute value of the element for that time. And when we are seeking the amount of any particular order of perturbations, we must proceed as in the astronomical case by selecting as far as may be times for observation when the disturbance in question is a maximum and all others are of minimum value. The practice of the observer will supply many artifices of this sort for eluding or grappling with difficulties which appear at first sight insurmountable. It is obvious, that when the object is to ascertain the steady and periodical variations of the meridian we should exclude from the comparison those days whose serenity is affected by what Humboldt has denominated magnetic storms; just as we should pass over days of violent winds and tempests in deducing the gradual rise and fall of temperature during the 24 hours. No attempt should be made to frame an hypothesis or even to hazard

a conjecture in regard even to the variations of the shortest period from one year's observations, however unremitted they may have been; but these observations may be of use in confirming a theory long entertained and well established by facts noticed in other places.

The observations of Graham, in 1772, which resulted in the detection of the diurnal variation of the magnetic meridian at London, have been repeated since in various parts of the world with increased delicacy and skill and with the same general result which is briefly described. The magnetized bar, free to place itself in the magnetic meridian, does not remain in one fixed position during the day but sometime in the morning, between six and eight o'clock as the average statement, it starts in a westerly direction and moves that way till between one and three in the afternoon; then it begins to retrace its steps back to the east again. These points of maximum and minimum declination are formed in every diurnal curve and at nearly the same hour. We shall hereafter see what the limits of the time are. There are two ways in which the bar regains its first position. In some places, as Paris for example, it arrives at its greatest eastern elongation again between eight and eleven o'clock in the evening and then remains stationary till the time of morning excursion has come round once more. In other places, as at Cambridge, it travels eastward till evening and then goes back to form a secondary point of maximum westerly deviation about three o'clock, A. M.; after which it passes eastward and recovers at eight o'clock the place it occupied 24 hours before. In certain cases, especially in northern latitudes, even when the secondary maximum and minimum are not formed, the bar does not remain stationary during the night but occupies nearly all the time from three P. M. to eight A. M. in returning through the space it

has just passed over in seven hours. Again, the arc traversed by the bar in its daily excursions varies perceptibly from one day to another; but the approximate law is, that in the six months from the vernal to the autumnal equinox, its value is between 13′ and 15′; and in the remaining six months the mean of the daily arc is between 8′ and 10′. But there may be single days when it amounts to 25′ and others when it is as small as 6′.

Gauss thinks that eight A. M. and one P. M. of mean solar time are never far from the periods of daily minimum and maximum declination in Gottingen and that part of the globe. It appears from a Report in regard to the magnetic state of the Russian empire for 1837 * that, at St. Petersburg, the greatest westerly position of the north end of the magnetic meridian is near two o'clock, P. M. and the opposite position is at eight in the morning with the exception of November, December, and January, when it occurs later. This is easily explained by the high latitude of the place when we come to consider the dependence of this daily motion on the sun. Since the declination is easterly in some parts of Russia, it follows that the maximum declination there is in the morning and the minimum in the afternoon. As the Report in question has been published with great care we extract a Table of the Monthly Means of the arc of daily excursion to show how near they correspond to the more extended means which we have mentioned above.

* Annuaire Magnetique et Météorologique du Corps des Ingénieurs des Mines de Russie. Année 1837. St. Petersburg. 1839.

St. Petersburg, 1837.

April	16.′2	October	6.′7
May	15.1	November	3.7
June	16.5	December	1.9
July	13.6	January	3.2
August	11.9	February	5.8
September	9.9	March	11.0
	83.2		32.3
	13.86		5.4

We have no occasion in this place to remark on the cause of this great inequality of arc in the different months, or on the times when the maximum and minimum occur. We only wish it to be observed that the daily curve, so perceptible in other places and so marked by its general uniformity of appearance, is clearly seen in the Cambridge observations. We have here referred to the Plates which represent some of these diurnal curves, but Table II. at the end will display in a condensed form, the results of 12 months' observation on this point. As the values for some of the months were deduced from scanty observations they cannot be brought into a fair comparison with more comprehensive means. If it shall appear that the times of maximum and minimum declination are embraced within the limits of a few hours, it is extremely important that observations should be made during those periods every day in the year to determine the precise moment when they occur each day and the arc of excursion. Means drawn from such abundant data might lead to a satisfactory solution of the daily changes and not leave them, as at present, to probable conjecture.

It appears from observations on various parts of our planet that periodical changes of days, months, years, and longer duration are

affecting its magnetic equilibrium; all of which come, with few exceptions, under the same general expressions so much so as to leave no doubt that they have a common origin. Hence it might be expected that if the corresponding curves of magnetic Declination were drawn for the same solar time in different places they would conform to each other and exhibit a kind of parallelism. But in addition to the orderly variations there are other perturbations of a sudden and irregular nature; and it becomes an object of extreme interest to inquire how far these are local and accidental and to what extent they must be regarded as general and proceeding from some grand central force. Such an examination was contemplated as among the good results of the simultaneous observations made in Germany, Russia, Italy, &c., an account of which may be found in Taylor's "Scientific Memoirs" and "The Russian Magnetic Annual" to which I have already referred; and a possible answer to an intricate question was held out as an inducement to engage in the magnetic crusade. The expected comparison exhibits surprising coincidences in most of the irregular movements of the Magnetometer as if the cause were coextensive with the range of magnetic posts. Hitherto our country and indeed this whole Western Continent has not been represented in this Congress of Nations for a scientific object; having been destitute of the means of contributing its portion to the general levy which has been made upon them. But the Term-day observations at Toronto, U. C., Philadelphia, and Cambridge will furnish materials for doing this now. Plate III. exhibits the diurnal curves of the October Term-day for the magnetic Observatories of Toronto and Cambridge. The declination of the meridian was very considerably deranged by perturbations during the first 12 hours of the Magnetic day (which always begins at 10 P. M. of Gott. M. T.) and affords, therefore, a favorable opportu-

nity of discovering the extent of extraordinary disturbances. Now a glance at the Plate betrays wonderful concert in the motions of the two remote bars; almost every digression of the bar at Cambridge and every change of curvature in the magnetic curve of that place has something corresponding to it in the curve of Toronto. There are a few singular exceptions; and, in a word, the bar at Toronto seems to have been more agitated and to have made greater excursions. But these discrepances throw no doubt on the subject; for they are just such as must be expected to occur in results which depend upon complex and multiform agents. A general and not a mathematical agreement is all that can be expected. The times which mark the limits of the eastern and western excursions in this fluctuating motion of the bars agree with great precision, except in two or three instances where the Cambridge curve lags behind five minutes or less. The parallelism appears at once from considering that the two curves, starting from points 12 minutes apart and making several digressions the same way of greater amount than the original arc of separation, do not cross each other except once; and this solitary instance will hardly be regarded as a transgression of the rule, since it arose simply from one bar being more affected by a particular wave of the magnetic tide than the other bar. On Plate II. is described the diurnal curve for the May Term-day. This too is singularly disturbed from 11 P. M., Gott. M. T. till 10 o'clock of the next morning. We have had an opportunity of comparing this with the similar curve observed by Professor Bache at the Girard College, in Philadelphia, and here again the instances of agreement make a stronger impression than the rare cases of discrepance. The correspondences are frequent and imposing; while the points which exhibit no such coincidence are few and of less importance. The agreement as to time is in almost every place precise; the disagree-

ment is confined chiefly to the extent or the existence of the motion. At $12\frac{1}{2}$, $7\frac{1}{4}$, $9\frac{1}{2}$ o'clock Gott. M. T. some excursions appear in the Philadelphia curve which have little or no counterpart in the Cambridge curve. They are deserving of notice because they are more considerable than any others of a local character which have been noticed and yet they do not, any of them, exceed 5′ of arc. But the remarkable excursions in Plate II. at *a*, *b*, *c*, *d*, *e*, *f*, are all faithfully represented on the Philadelphia curve. Only the upper branches which belong to the easterly motion are exceeded by the corresponding simultaneous movement at Philadelphia, while the grand excursions at the bottom of the Plate, which are due to the westerly motion or increase of declination, go beyond their parallel passages in the Philadelphia curve. For instance, the branches *b*, *c*, *d*, *e*, *f*, extend respectively 10′, 12′, 11′, 5′, 6′, farther in the Philadelphia than the Cambridge curve. The reverse happens at *g*, *h*, *i*, where the Cambridge branches go 13′, 30′, $14\frac{1}{2}$′, farther west than the analogous ones at Philadelphia. The close coincidence of the times when the direction of any great motion changes, observed at Toronto, Philadelphia and Cambridge, makes it probable that the longitudes of the three places are known to a close approximation, or, at least, that the differences of longitude between these places are not much in fault; for, if they were, it would by its effect upon the regulation of the clocks prevent a coincidence of magnetic disturbances which actually existed and make the appearances different from what we observe; unless we can suppose what seems extremely improbable, that the constant error of the time should by chance balance precisely the actual want of coincidence in the arrival of the magnetic impulse at each place so as to deceive us in the final result. This, however, is a subject which requires to be pursued longer. The observations contemplated in coming years will, it is believed, fur-

nish the materials for a comprehensive study of this problem and enable us to determine with more confidence than can be reposed in the comparison of places not widely removed from each other the extent and the laws of what are now classed among the irregular perturbations of the magnetic equilibrium. All attempts at induction now must be considered as subordinate to the final discussion; but they have their purpose in indicating from time to time the direction to which the attention of observers should be particularly turned. To this end, an arrangement supplementary to the large plan was completed with Lieutenant Riddell for making simultaneous observations on the declination Magnetometer at Toronto and Cambridge, at intervals of *two minutes* from $0^h\ 45'$ to $1^h\ 45'$ P. M. Gott. M. T. Such observations were accordingly taken at Toronto for the assigned hour every day (Sundays excepted) from October 23d to November 19th inclusive. Similar observations were made in Cambridge at the same time. Professor Bache would gladly have been a partner to this project but an accident prevented him from being informed of it in season. Another agreement was formed to observe *every vibration* of the bar during one hour from 9 to 10 P. M. Gott. M. T. for one week commencing with the 4th of January, 1841. Fig. 2d of Plate III. exhibits the hourly curve for the 28th of October; the upper one being the Cambridge curve and the lower one the Toronto curve. Here it will be noticed that the changes of flexure in the two curves are generally coincident in time and when they vary the maximum difference does not exceed the interval between two successive observations.* The hour selected for the January obser-

* While this Paper was passing through the press we received an account of the proceedings of the Irish Academy at a recent meeting, containing some remarks by Professor Lloyd on contemporaneous observations at short inter-

vations appears, on the whole, unfavorable for drawing conclusions in regard to the concurrence of abrupt changes of the magnetic state of the earth as it is the period when the bar is most quiet. It is of advantage, however, to know that the periods of repose are independent of longitude and the same absolutely for different places; an inference which the observations certainly authorize us to make. We shall have occasion hereafter to remark on the degree to which observations made with the Gauss Magnetometer and Lloyd's Declination instrument are comparable.

Whatever interpretation may be given to the anomalous changes to which the declination of the magnetic meridian is subject, there can be little hesitation in admitting that the regular and periodical ones having their expression in functions of solar time are dependent upon the sun's influence as an exciting and sustaining cause. The theory which we may adopt as to the nature of the earth's magnetism does not essentially affect this statement. If magnetism, as an independent property, exist in particles of the earth's mass, it may have its equilibrium disturbed by temperature as heat is known to affect the state of ordinary steel magnets; and as in the passage of the sun through his daily and yearly path parts of the earth's surface are heated to unequal degrees, that change of the magnetic fluid may be induced which shall result in periodical alterations of the magnetic meridian. But a strong body of evidence can now be summoned to prove that magnetism has no existence as an independent fluid or property of matter; but that

vals by himself and Professor Bache on the small variations of magnetic declination. The result of the comparison has convinced him that such changes do not occur simultaneously at places so far removed from each other as Dublin and Philadelphia. Therefore they will not, as was suggested, furnish a safe method of deducing differences of longitude.

polarity is one of the phases of the electrical fluid. The magnetic character of currents and the facility with which they are excited by motion and differences of temperature are now well approved facts. The earth's rotation; the sun's heat; volcanos; and the great eastern and western metallic ranges furnish all the materials and machinery that are needed for making the planet a grand electro-magnet. Aside from the magnetic phenomena, the existence of the earth's currents is thought to have been shown by direct experiment. If we do not admit them as the prime source of Terrestrial Magnetism they offer themselves as sufficient and satisfactory causes of the observed fluctuations about the average state. The belief in the earth's currents seems unavoidable; and if any proportion subsists between their magnetic energy and those of artificial electro-magnets the fund of magnetism which they supply must be ample to explain all the chief facts of the earth's magnetism. But if we adopt Gauss's estimate that the whole magnetic power of the earth is equivalent, on the average, to 7,8 steel magnets of 1 pound weight magnetized to saturation for every cubic metre, there may be some difficulty in conceiving of sufficient iron ore in the earth to furnish the depositary of such a magnetic force according to the common motion of steel magnets. Besides, there may be a question whether it is philosophical to look round for any such new principle when it is not needed to explain the facts. If currents are finally adopted not as the auxiliary but the main and standing cause of Terrestrial Magnetism, the unavoidable fluctuations and occasional overflowings with the daily ebb and flow to which from their nature and remote source they must be subject afford a liberal explanation of the regular and irregular perturbations in the declination of the meridian.

In so complex a subject, no attempt could be made at present to

explain the *modus operandi* by which the sun's rays affect the position of a magnetized bar. It is much to have the dependence of these changes upon solar time clearly established. The moments at which the maximum and minimum points of the diurnal curves occur oscillate between certain limits; it is important, therefore, to have the diurnal curves for places removed many hours from each other in longitude, in order that a difference of time depending upon the constant difference of longitude may not be masked under the variation to which the time is subject at the same place. Now the Observatories of Gottingen and Cambridge differ in longitude $5^h\ 24'\ 16''$; it is plain, then, that if there be such a relation to the solar time of each place it must appear even in the curves of a single day. And so it is found by an examination of the Cambridge times and those published by Gauss for Gottingen and contiguous places that a difference equal to the difference of longitude exists in the mean times of the greatest eastern and western declination of the magnetic meridian. The extremes occur at nearly the same solar hours at each place, so that when we are observing our minimum in the morning the observer in those eastern longitudes is taking note of the western excursion of his bar; for at both places the interval from minimum to maximum is between five and six hours. The rest of the 24 hours is expended in the return of the bar back towards the morning position except in those cases where a secondary maximum and minimum occur; and if this unequal time of passage over the same arc cannot be explained it is analogous to what is known to be true of the rise and fall of the temperature on the earth. The heating requires a shorter time than the cooling process; and whatever depends on the heating and cooling process will of course be subject to the same inequality. And in regard to all the magnetic changes which are attributed to the

solar influence it is to be observed that no more exact uniformity is to be expected in them than in the legitimate and acknowledged influences of the sun ; that is to say, the earth's temperature.

Yet farther supplementary to the plan recommended by the Royal Society, a series of observations has been undertaken at Cambridge with the express object of throwing additional light on this interesting inquiry. As early as May, 1840, the observations took a wider range so as to furnish a diurnal curve not only for the Term-day but also for several other days in the same part of the month. The following Table shows the days over which the observations were extended, including the prescribed Term-days.

		Term-day.	Extra Days.
1840.	May	May 29	May 21, 22, 23.
	June	June 24	June 21, 22, 23, 25, 26, 27, 28, 29, 30. July 1.
	July		July 24.
	August	August 28	August 29, 30, 31. September 1.
	September	September 23	September 21, 22, 24, 25.
	October	October 21	October 20, 22, 23, 24.
	November	November 27	November 23, 24.
	December	December 23	December 21, 29.
1841.	January	January 20	January 22, 25.
	February	February 26	February 24. March 1.

On all the preceding days observations were made during the 24 hours so as to furnish materials for drawing as many diurnal curves. The intervals between the observations were not always five minutes as on the Term-days. Thus in May the interval was 15 minutes and in June and July 20 minutes. Again, in August the interval was only four minutes. In August, reasons appeared for recording the Thermometer at intervals of 20 minutes on all the days when the Magnetometer was observed. This was sufficient to give all the regular daily thermometric changes. In October, the Barometer was observed every 20 minutes during the five days. The observations on the Barometer have not been repeated as they did not promise to facilitate the inquiry upon

which we were engaged; but the Thermometer has been observed regularly since the first trial every 20 minutes whenever magnetic observations are made. The magnetic observations were conducted on all these days with the same strictness as on the Term-days at intervals such as have been denoted; 12 or 13 readings determining the place of the magnetic meridian for every required period. There may be times during every time of observation when the arc of vibration is too large to allow of this process and then the 12 readings are suspended and the extreme limit of every oscillation is recorded. The expense of the Plates has precluded the idea of publishing all the diurnal curves which have been thus obtained. A specimen has been selected which will give an impartial view of the whole investigation. On Plate VI. the thermometric curves corresponding to the five October days may be studied by attending to the directions given on the face of it. The remarkable points are arranged in the following Table.

Abstract of the October Thermometric Curves.

Date. Civil Time.	Time of Minimum Heat. Cambridge M. T.	Thermometer.	Time of Maximum Heat. Cambridge M. T.	Thermometer.	Daily range of Thermometer.
Oct. 21	6h 10′ A. M.	50° 20′	1h P. M.	54°	3° 40′
" 22	1 "	46	2 "	51 30′	5 30
" 23	3 50 "	34	2 "	62	28
" 24	6 50 "	40 40	2 40′ "	53	12 20
" 25	1 30 "	37	11 A. M.	47 20	10 20
Means.	3 52 "	41 36	1 20 P. M.	53 34	11 58
Mean curve	6 10 "	43	2 "	52 15	9 15

The absolute changes of temperature from day to day cause the difference between the means of the numbers attached to the five days and the mean curve, as in the two last lines of the Table. The mean curve is drawn by adding together the figures observed at

the same time on the several days and dividing by 5. The result is the mean temperature for that period of the day. Then the times of maximum and minimum of the mean curve are found from the greatest and least values of these mean results. The absolute variations of temperature from one day to another vitiate to a certain extent this process. The same method is pursued for laying down the mean diurnal magnetic curves; the absolute changes of magnetic declination from one day to another are too inconsiderable to produce any great error in the result. But the mean of the daily magnetic curves is materially injured by the *irregular* perturbations of the magnetic meridian. Hence it is supposed that the mean thermometric curves have a fair comparison with the mean magnetic curves. For the sake of facilitating this comparison, the following abstract is given of the single and mean diurnal magnetic curves which are drawn at length on Plate IV.

Date. Civil Time.	Time of Minimum Declination. Cambridge M. T.	Readings of the Scale.	Time of Maximum Declination. Cambridge M. T.	Readings of the Scale.	Daily Range.
October 21	8^h 6′ A. M.	102.562	0^h 28′ P. M.	92.354	10.208
" 22	8 36 "	104.333	11 46 A. M.	93.364	10.969
" 23	9 11 "	103.375	2 51 P. M.	96.031	7.344
" 24	8 16 "	103.208	2 31 "	95.396	7.812
" 25	5 11 "	101.740	1 41 "	92.302	9.438
Means	7 52 "	103.044	1 27 "	93.889	9.154
Mean curve	8 36 "	102.250	3 1 "	94.368	7.882

We have now the following results of comparison:

Times of maximum temperature	range	from	11^h	A. M.	to 2^h 40′	P. M.	$= 3^h$ 40′.
" " declination	"	"	11 46′	"	to 2 51	"	= 3 5.
" of minimum temperature	"	"	1	"	to 6 50	A. M.	= 5 50.
" " declination	"	"	5 11	"	to 9 11	"	= 4 hours.

It appears, then, that the times of maximum and minimum magnetic declination are comprised within narrower limits than those of the

greatest and least temperature; and yet the last phenomena, as every one believes, depend on the apparent daily motion of the sun. It is to be observed that these days were selected and the curves published before the comparison was made. They are to be regarded as a fair index of the whole series of observations of a similar character taken in each month since August, 1840, inclusive when the thermometric and magnetic changes were first observed in connexion. As far as any dependence can be placed upon them, they authorize us in stating that the diurnal magnetic curve is a more exact and definite function of solar time than the regular daily change of temperature. In whatever particular the comparison is made the preference attaches to the magnetic curves. We have seen how it is in regard to the *limits* of the time of maximum and minimum. The greatest variation of any daily range of the thermometer from the mean of the ranges is more than $\frac{17}{12}$ of the mean range. The greatest variation of any magnetic range from the mean of the magnetic ranges is less than $\frac{1}{5}$ of the mean of the magnetic ranges. The most observable deviations from mean results in the magnetic observations pertain to the times of maximum declination of October 21–2 and 22–3 and the times of minimum declination of October 25–6. If they were excluded, the limits of the times of maximum declination would be reduced from 3 hours to 1 hour and 10 minutes and of minimum declination from 4 hours to $1^h\ 5'$. In regard to the first of these days, an unusual and irregular derangement of the magnetic equilibrium occurs between 1^h and 3^h P. M. Cambridge M. T.; and there is reason to think that the maximum declination, if the extraordinary influence could be eliminated, would fall between these disturbed hours. There is even a doubt whether now the western excursion at 3 P. M. ought not to be taken as the western limit of that day. The irregular

perturbations which do not generally begin before 7 or 8 o'clock in the evening commenced their operations on this day earlier than usual by many hours. We are confirmed in this opinion by examining the curve of the next day from 10 o'clock Gott. M. T.* This curve is a continuation of the first from the place where it ends at the right hand of the Plate; and we see from it that the perturbations continue during the whole night and morning till nearly the time of the next minimum; one digression of the Magnetometer within 30 minutes about an hour before midnight of October 21st amounting to 20′. These agitations are felt at intervals till the following midnight and may be allowed any influence that is thought justly attributable to them in hastening the time of maximum of the second day. It is admitted that this maximum appears satisfactorily formed on the curve so as to leave no doubt that the time selected for it, 11^h 46′ A. M. Cambridge M. T., is correct. And further, in regard to the minimum of the last of the five days, there may be a question what precise moment between 5 and 7 o'clock A. M. Cambridge M. T. should be chosen. It seems probable that the minimum should be formed earlier than usual on this day as the maximum occurs later than the average time; so that the whole curve from the point of minimum to that of maximum takes a wider sweep of time than usual; a glance at the Plate makes this clear. These explanatory suggestions as to the extreme cases, if valid, will give still greater preëminence to the diurnal magnetic curves over the cotemporaneous thermometric curves so far as relates to the present comparison. But it is not at all necessary for our purpose to press this apology. No abatement for similar reasons is required in regard to the thermometric curves. Although

* The commencement of the Magnetic day is in all cases at 10 o'clock P. M. of mean Gottingen Time.

occasional tempests of heat and cold occur they cannot compete with the irregular disturbances of the magnetic force, where a change of 20′ occurs in half an hour while the greatest range from minimum to maximum on any of these days is only 11′. There is safety then in affirming that the changes in the declination of a magnetized bar would be a better index of solar time than a standard thermometer; or again, that starting from a known hour of the day with a given declination we might venture a closer prediction, founded on calculation, as to the position of the same bar 6 hours afterwards than would be safe with a thermometer under like conditions; care being taken of course to select that portion of the day which is most free from *extraordinary* magnetic and thermometric changes.

Let us now see how this conclusion is sustained by more extensive observations. To this end Tables are presented of the Monthly Means, comprising the mean periods of magnetic and thermometric minima and maxima since this kind of observation was instituted at the Cambridge Observatory.

Thermometric Table.

Months.	Number of days observed.	Time of the Mean Minimum Cambridge M. T.	Value of the Mean Minimum.	Time of the Mean Maximum. Cambridge M. T.	Value of the Mean Maximum.	Mean Daily Range.
August	5	4^h 56′ A. M.	58° 36′	2^h 36′ P. M.	77° 48′	19° 12′
September	5	5 56 "	41	2 16 "	63 48	22 48
October	5	6 16 "	43	2 06 "	52 06	9 06
November	3	5 36 "	25 48	2 56 "	35 20	9 32
December*	3		16 40	0 36 "	29 50	13 10
January	3	6 36 "	24 20	2 36 "	33 30	9 10
February	3	5 56 "	20 20	2 16 "	39 20	19 00
Means		5 53 "	32 49	2 12 "	47 23	14 34

* Time of minimum for this month is 6^h 26′ P. M. Cambridge M. T. From this time the thermometer rises during 18 hours till the period of maximum.

Magnetic Table.

Months.	Number of days observed.	Time of Mean Minimum Declination. Cambridge M. T.	Reading of the Scale for Mean Minimum.	Time of Mean Maximum Declination. Cambridge M. T.	Reading of the Scale for Mean Maximum.	Mean Daily Range.
May	3	6h 26′ A. M.	114.523	1h 06′ P. M.	100.208	14.315
June	10	6 56 "	110.528	1 56 "	100.875	9.653
August	5	6 16 "	126.564	1 44 "	115.135	11.429
September*	5		111.925	11 36 A. M.	96.452	15.473
October	5	8 56 "	102.250	3 1 P. M.	94.368	7.882
November	3	8 51 "	111.958	1 16 "	95.927	16.031
December	3	8 06 "	100.767	3 16 "	92.226	8.541
January	3	9 16 "	98.871	3 26 "	90.062	8.809
February	3	8 16 "	99.816	3 16 "	91.090	8.726
Means		7 53 "	108.578	2 04 "	97.371	11.206

The times of the monthly mean minima of temperature for the seven months from August inclusive, December being rejected as anomalous, range between 4h 56′ and 6h 36′ A. M. so as to be all comprised in the space of 1h 40′. Similar times for the maxima points are included within 2h 20′ from 0h 36′ to 2h 56′ P. M. It also appears that the times of the monthly means of minimum declination for the same months together with May and June, if we leave out September, come between the limits of 6h 16′ and 9h 16′ or an interval of 3 hours, while the times of mean maximum declination, if we exclude September, are confined within the limits of 1h 06′ and 3h 26′ or 2h 20′. All circumstances being considered, these results are favorable to the theory which assigns to the daily changes of magnetic declination as precise a dependence on solar time as can be claimed for the corresponding variations of temperature. As far as coincidence of time between two phenomena proves one to be the cause and the other the effect, the daily oscillations of the magnetic meridian are as clearly referrible to the sun's agency as the familiar rise and fall of local temperature during the same period. It should

* The time of mean minimum for September is by the observations 8h 31′ P. M. Cambridge M. T. From this time the western deviation increases till 11h 36′ A. M., the time of maximum declination.

be considered that in the instance of magnetism the limits are estimated for nine months while those of the thermometer extend over only seven months. The longer period affords of course a wider field for the display of extreme cases. The disadvantage to magnetism is increased by the influence which the remarkable fluctuations of magnetic influence exert upon the regular periodic phases. As observations on temperature are hereafter to be made parallel with those of magnetic declination we shall be able, at some future time, to present the results of a larger and more satisfactory comparison of the two sets of changes than our present materials can afford. The limits for the times of maximum declination and temperature are the same; the limits of minimum declination are greater than those of minimum temperature. The considerations which have led to the exclusion of some of the observations must now be stated. First, we consider the mean thermometric curve for December. The maximum which falls 36 minutes after noon is earlier than usual; while the minimum is 12 hours from the average time of greatest cold and would come at $6^h\ 26'$ P. M. instead of the morning. We suppose therefore the true time of maximum for this month to be merged under irregular changes so as to escape notice even in the mean result. This mean was derived from three days' observations. The minimum for one of the days happened at $5^h\ 56'$ A. M.; for another at $2^h\ 14'$ while on the third day the changes of temperature were so frequent and disorderly from alterations in the wind and sudden variations from a clear to an overcast sky that the lowest temperature is at $6^h\ 14'$ P. M. and the highest at $6^h\ 56'$ A. M. The eccentricities of this day are sufficient to vitiate the whole result and prevent the real time of minimum from appearing even in the mean of several days. To guard against this source of error it is important that the monthly means should

be deduced from as large a number of days as can be conveniently observed; every day in the month would not be superfluous. This could easily be done at Cambridge if provision were made for conducting the two hourly observations on every day according to the English plan. But these daily observations of the Magnetometer have not been attempted and would be impossible with the present resources of the Observatory.* It is not surprising that what occurred once in six months' observations on the temperature should have exhibited itself also in the diurnal curves of the Declination Magnetometer. This brings up the case of the September magnetic curve which we have excluded from any part in determining the mean quantities because it was calculated to injure the just average values which we are endeavouring to reach. The curve in question may be traced out on Plate V. by following the directions there given and a single glance will show how the times of its extreme elongations differ from those of the other three mean curves which are on the same Plate. The general appearance of these three curves indicates a law to which the fourth curve must be a palpable exception and transgression. An attention to the separate diurnal curves for the five days in September from which the mean curve is reduced will afford an explanation of this violation of what we may regard a principle of the earth's magnetism. On September 20–1, (Magnetic day, commencing as in all cases at 10 P. M. Gott. M. T.) we have these three maxima:

							Readings of the Scale.
1st at	$11^h\ 36'$ P. M.	Cambridge	M. T.,	September	20	=	82′.5.
2d "	4 56 A. M.	"	"	"	21	=	79 .5.
3d "	11 56 A. M.	"	"	"	21	=	83 .5.

* A Director with three Assistants all of whose time should be devoted to the work have been considered elsewhere as the full *personnel* of such an establishment.

and these eight minima:

						Readings of the Scale.
1st at	3^h 14′	P. M.	of September	20	=	112.
2d "	5 46	"	"	"	=	116.
3d "	7 56	"	"	"	=	123.
						Reading at 8^h 16′ P. M. 109.
4th "	8 26	"	"	"	=	125.
5th "	0 46	A. M.	"	21	=	116.
						Reading at 1^h 06′ A. M. 98.5.
6th "	1 54	"	"	"	=	117.
7th "	6 06	"	"	"	=	115.5.
8th "	2 31	P. M.	"	"	=	108.

The whole range of the Magnetometer during this day is 45′.5. The smallest elongation from the meridian is at 8^h 26′ P. M. and the greatest at 4^h 56′ A. M., as the lowest number of the scale indicates greatest declination. But these like the rest of the maxima and minima for this day are mere lawless excursions caused by sudden derangements and have no connexion with the regular diurnal magnetic curve. Between the 3d and 4th minima the bar moves to 109′ or 14′ in arc in the space of 20 minutes and then falls back eastward again. So between the 5th and 6th minima the bar moves to 98′.5 of the scale or 18′ forward and back again in 1^h 8′. The time occupied in going from the 2d or greatest maximum to the 7th minimum is only 1^h 10′ although the space is 36′ or three times the ordinary daily range of the magnetic meridian for this month. If these perturbations were less frequent and not spread over the whole 24 hours means might be devised of shutting out their influence and interpolating the true daily curve in the gap left by their removal. But on this day no safe way of making the reduction presents itself and the times of maximum and minimum are both left indeterminate.

On September 22 – 3, the Magnetometer was more quiet; occasional oscillations of considerable extent occur but the maximum point is very regularly formed at 11^h 36′ A. M. and the minimum though less definite is placed at 6^h 06′ A. M. On September 24th westerly disturbances take place between 4^h 36′ and 7^h 36′ A. M., the time when the minimum generally shows itself; the effect is to bring the mean curve at this period too far to the west or to make the apparent mean time of maximum earlier than it is in fact or would appear if the observations were free from irregular variations. These derangements do not cease till nearly the close of the third magnetic day so as to throw uncertainty on the time of maximum of this day also.

September 24 – 5, (Magnetic day.) Disturbances break out again in strange forms. This day was affected by wholly unprecedented motions distinguished not so much for their extent as for their number and the rapidity with which they succeeded one another. A faint idea of them is conveyed by looking at those which occurred between 7^h 20′ A. M. and 7^h 40′ A. M. Gott. M. T. of October 22d, represented on Plate IV. The direction of the motion changed 60 times or more from east to west and back between 1^h and 2^h P. M. Gott. M. T. The whole sweep of the needle for this day is only 26′, an area much less than is often traversed in the diurnal motion; but the number and frequency of the oscillations is unparalleled. The greatest declination occurs at 3^h 06′ A. M. Cambridge M. T. and the least at 3^h 36′ P. M.; but another minimum more nearly resembling the regular daily minimum appears at 5^h 36′, A. M.

September 25 – 6, (Magnetic day.) The magnetic storm has subsided. The curve for this day is as quiet as that of the 4th day on Plate IV. The eye readily perceives that now we have only regular diurnal changes and that the times of greatest and least

elongation from the astronomical meridian can be trusted. The mimimum is at 6^h $26'$ A. M. and the maximum at 0^h $16'$ P. M. Cambridge M. T.

We have here ample and abundant explanation of that singular figure assumed by the mean daily curve for September. We look for the time when some method shall be devised for evading the errors which such extraordinary changes of the magnetic declination entail on the mean values of the regular variations. If hereafter the dependence of the magnetic declination upon the hour of the solar day shall be so accurately discovered as to be reduced to a Formula we may be able, by the help of that portion of the curve which is undisturbed, to calculate the remainder. At present this Formula must be an empirical one, derived from the faulty observations themselves and in its defective state is available only in a partial degree for purifying these observations. Our chief resource now lies in levelling, as far as possible, the excessive excursions by the influence of undisturbed days with which they are combined; though this can be done only by sacrificing in part the more perfect observations. The case in hand teaches us that this method will not always be effectual in bringing out approximate results. The irregularities may be so great as to overrule the regular law. This is less likely to happen in proportion to the number of days that can be observed in each month and hence again the necessity of deducing our means from as numerous observations as can be obtained.

The dependence of the diurnal magnetic changes on solar time rests upon the evidence of a large number of observations collected from remote sources. But there is a difficulty in conceiving of the exact manner in which this connexion is sustained. Perhaps it will always be a hopeless task to attempt to trace the

intricate path by which the heat deposited at one moment in the centre of our system arrives at its final result of causing a deviation in the direction of the magnetic meridian. And while this is the case, it will be impossible to enter upon the mathematical analysis of the problem and deduce formulæ which can be used for detecting the errors of theory or correcting or supplying the deficiencies of observation according to the well-known relation subsisting between these different methods of investigation. But the artifices of analysis will frequently take hold of cases which cannot be approached by any direct process. The observations allow us to proceed upon the ground that the declination or the ordinate of the diurnal curve of declination is a function of the solar day. It may, then, like any other periodic function be supposed to be expressed in a series of terms arranged according to the sines and cosines of the time and its integral multiples.* Thus if

$t =$ the time expressed in parts of a day as its unit,
$d =$ the ordinate of the diurnal curve for the time t,
$\pi =$ the ratio of the circumference to the diameter,
$n =$ any integer whatever ;

and if S denote the sum of the terms which correspond to the different values of n, we have for the general form ;

$$D = A + S . C_n \sin. 2 \pi n (t + c_n).$$

The values of A, C_n and c_n are readily determined by the following formulæ. Let observations be taken at equal intervals for several whole days and let

$h =$ time of observation counted from the beginning of each Magnetic day in parts of a day as unity :

* It was according to this mathematical developement that Professor Peirce calculated the empirical curves.

D_h = the mean of the observations taken at the time h of each day.

Then if S' denote the sum of all the terms which correspond to the different values of h, we have

1. $m\,A = S'\,D_h$

m representing the number of intervals on each day.

2. $m\,C_n \cos. 2\,\pi\,n\,c_n = 2\,S'\,D_h \sin. 2\,\pi\,n\,h$.

3. $m\,C_n \sin. 2\,\pi\,n\,c_n = 2\,S'\,D_h \cos. 2\,\pi\,n\,h$.

There is no known periodic function which does not admit of developement according to the sines and cosines of the time and its integral multiples and in the absence of positive evidence the same thing may be assumed in regard to that under present consideration. The constant A, being equal to $\frac{SD_h}{m}$, is the mean of all the partial results obtained from observation for the several intervals into which the day is distributed for this purpose. By substituting different values for n we obtain an indefinite number of terms out of the general one $C_n \sin. 2\,\pi\,n\,(t+c_n)$. It appears, however, from the calculation that the series rapidly converges so that the first four or five terms are sufficient to give the declination within a degree of exactness corresponding to the accuracy of the observations themselves. Dividing the 2d equation by the 3d, we have the value of the tang. $2\,\pi\,n\,c_n$; and multiplying equation 2d by $\cos. 2\,\pi\,n\,c_n$, and equation 3d by $\sin. 2\,\pi\,n\,c_n$, and adding them together we readily find the value of C_n. Thus, if the numbers 1, 2, 3, be successively taken for n, we shall have the following equation for finding the approximate declination, or the empirical magnetic curve:

$$D = A + C_1 \sin. 2\,\pi\,(t + c_1) + C_2 \sin. 4\,\pi\,(t + c_2) + C_3 \sin. 6\,\pi\,(t + c_3).$$

The empirical thermometric curve is calculated on the same principle by this formula:

$$T = B + D_1 \sin. 2\,\pi\,(t + d_1) + D_2 \sin. 4\,\pi\,(t + d_2) + D_3 \sin. 6\,\pi\,(t + d_3).$$

Plates IV. and VI. will show how rapidly the series of both formulæ converge and the limit of error incurred by dropping all the terms after the 5th. In the formulæ for October the 5th term of the declination cannot exceed ,034 of a minute and the 5th term in the value of the temperature cannot be greater than ,4 of a degree of Fahrenheit. From the nature of an empirical curve our confidence in it must bear some proportion to the accuracy of the observations. If these observations are exposed to errors from any cause, as we have seen that they are, the empirical curve will suffer, though in a less degree, on their account. The error which in a single diurnal curve is left in its naked state is of course diminished in the mean curve of several days by the levelling influence which all the days exercise upon any single one. But this process reduces, it does not extinguish the error. The passage from the mean of the observed curves to the empirical curve carries us one step further towards the true expression of the actual phenomena of magnetism. For a considerable mean error arising from irregular disturbances, which in the first is concentrated upon a single moment, will be in the second curve distributed over the whole day and may therefore disfigure the general character of the day though it does not distort extremely any particular part. Moreover, it is easy in calculating the values of the constants in the empirical formula to omit observations of an extraordinary character and which are notoriously burdened with strange anomalies. This we see on Plate V. in the instance of the September days and to a less extent in October. The whole character of the curve for the former is changed from what we have reason to believe is the real diurnal curve; although it has escaped those large and prominent excursions which appear three or four times in the mean of the observed curves. In seasons of great disturbance it would be more safe to rely on the empirical curve than the observed curve; but in quiet

times, as the empirical curve borrows all its truth and expression from these observations, the latter have more claim to consideration than the calculated places. It is obvious from the principle on which the empirical curve rests and the manner in which the constants are deduced that they will answer only for one curve and must be calculated separately for every new curve that is required. As the form of these equations and the time, which is the only variable, are the same for each curve, whatever changes exist in the diurnal curve from one month to another in the year must be indicated by a corresponding change in the independent constants. And moreover if there be, as the comparison of recent and old observations lead us to believe, secular periods for the magnetic declination, they will betray themselves by slow variations in the mean yearly values of these same constants. It becomes then an object of curious inquiry to ascertain what are the values of $\mathcal{A}$, C_1, C_2, C_3 ; c_1, c_2, c_3, &c. for every month in the year; and after this their mean values from one year to another. It is possible that the laws of the secular changes may be better studied from the variations of these constants than from immediate observations. Four of these formulæ are here given with the names of the months to which they belong, and the number of days employed in calculating them ; t = the time from 0^h Gott. M. T.

June, 10 days. Declination*
$= 9°17',3 - 3',853 \sin(t - 16^h 21^m 24^s) - 1',537 \sin 2(t - 9^h 31^m 24^s) - 0',948 \sin 3(t + 0^h 27_m 9_s) - 0'644 \sin 4(t - 4^h 22^m 9_s)$.
August, 4 days. Declination
$= 9°13',9 - 3',907 \sin(t - 15^h 12^m 47^s) - 2'009 \sin 2(t - 9^h 46^m 58^s) - 0',878 \sin 3(t + 0^h 51_m 15_s)$.
September, 5 days. Declination
$= 9°21',9 - 2',932 \sin(t - 9^h 34^m 18^s) - 1',530 \sin 2(t - 8^h 12^m 8^s) - 0',494 \sin 3(t + 1^h 32^m 29_s) - 1',090 \sin 4(t - 0^h 29_m 58_s)$.
October, 5 Days. Declination
$= 9°18',7 - 1',575 \sin(t - 13^h 0^m 42^s) - 2',379 \sin 2(t - 10^h 40^m 58^s) 0',508 \sin 3(t - 0^h 4_m 58_s) - 0',034 \sin 4(t + 0^h 12_m 32_s)$.

* The first term in the value of the declination is obtained directly in parts of the scale and is afterwards reduced to absolute numbers in the usual way of deriving the real declination from the reading of the scale. This process will be soon explained.

Here we close our investigation of the diurnal magnetic curve. The existence of such a curve regularly formed every day cannot be doubted; its general uniformity is also very observable. The limits of the times of maximum and minimum declination in different longitudes show conclusively that it is in some way connected with local solar time. Developing the declination according to the most general form of periodic functions we have obtained the preceding formulæ from which the empirical curves drawn on Plate V. were calculated. These calculated curves stand there side by side with the mean observed curves by which the constants of the formulæ were determined. The calculated curve, as we might expect, is less broken than the mean curve; still, the two agree in a striking manner and the greatest deviations are in those months which suffered most from magnetic perturbations. In June and August the empirical curve and the mean curve keep close together and these were periods of unusual magnetic repose; for in the mean of the latter month the disturbed Term-day was omitted. June was most quiet of the two, and shows it by a superior agreement between its mean and empirical curve. If there were no permanent change of declination but only the daily oscillation uninterrupted by disorderly fluctuations, the meridian would swing day after day through the same arc; and a few observations would be sufficient to establish a rigorous formula which would evolve an empirical curve strictly coincident with the observed curve. The want of this uniformity is felt in the variation of the constants of the formulæ already given. This simplicity does not exist in the motions of the heavenly bodies any more than in the magnetic movements. But the analysis is different. In astronomy we know the cause of the disturbance and allow for it at once without deranging the general analytical expression. In the other case we have no theory, no hypothesis; and the mathematical

form must vary with the observations. Hence the difference between the constants in the formulæ for the four months. They are no greater than might be expected from the known change of absolute declination from day to day, the limits of the times of maxima and minima and the longer and more irregular derangements which beset the diurnal movement. The mean curves of many months, drawn from the most abundant materials, are requisite for investigating the law by which these constants vary and rendering them available for calculating the secular periods of the earth's magnetism. We think it is apparent from all that has been adduced, that the diurnal magnetic curve is as clearly a function of solar time as the daily thermometric curve. We are not to expect any greater uniformity in the effect than in the cause. If the thermometric curve is sometimes imperfectly formed, the same thing may happen to the magnetic curve without destroying our belief in its connexion with the sun. The change of constants in one class of formulæ appears likewise in the other, as the three following thermometric formulæ make manifest:

August, 5 days. Temperature

$= 67^\circ{,}6 + 8^\circ.8 \sin(t - 15^h\ 57^m\ 28^s) + 0^\circ.9 \sin 2(t - 5^h\ 34^m\ 56^s) + 1^\circ.1 \sin 3(t + 0^h\ 44^m\ 56^s)$.

September, 5 days. Temperature

$= 50^\circ{,}2 - 10^\circ.0 \sin(t - 13^h 38^m 54^s) - 3^\circ{,}2 \sin 2(t - 9^h 31^m 4^s) - 0^\circ{,}3 \sin 3(t - 2^h) - 0^\circ{,}8 \sin 4(t - 4^h 39^m 48^s)$.

October, 5 days. Temperature

$= 47^\circ{,}7 - 3^\circ{,}8 \sin(t - 14^h 21^m 44^s) - 0^\circ{,}8 \sin 2(t - 9^h 17^m 36^s) - 0^\circ{,}4 \sin 3(t - 6^h 35^m 25^s) - 0^\circ{,}4 \sin 4(t - 0^h 38^m 12^s)$.

It still remains to discuss briefly those disturbances of the magnetic meridian which have no apparent law. We have occasionally alluded to them as irregular perturbations which produce perplexity in ascertaining the true diurnal curve. We are to inquire whether even they must be regarded as wholly inexplicable or whether they cannot be connected in coincidence of time at least with other well known phenomena of nature. There are few days in the year

when strange fluctuations of greater or less amount are not exhibited; but there are some periods distinguished above all others by their remarkable frequency and magnitude. We annex a brief history of each month in this respect.

1840.

March 27–8. No perturbations of importance; only two unusual excursions, one at 2^h 45′, A. M. Gott. M. T. (March 28) and the other at 4^h 15′, A. M.

April. The observations of this month are very defective.

May 29–30. Term-day. Irregular disturbances of large amount, from 11 o'clock, P. M. Gott. M. T.(May 29) to 12^h of May 30. The whole sweep of the instrument through the day is 57′,2; and once, between 3^h 50′ A. M. and 4^h 10′ the declination changes 47′, 2 in 11^m or 4 times the average daily swing from maximum to minimum. The other days observed in May were not distinguished above the average by perturbations.

June. The ten days observed in this month were all unusually quiet.

July 24–5. Between 6 and 8 o'clock, P. M. Gott. M. T. (July 25) the arc of vibration of the Magnetometer amounted to 20′ so as to require the substitution of its extreme limits instead of the 12 readings at intervals of 10 seconds. But this large movement was not accompanied by any considerable change of absolute declination and the whole magnetic day was undisturbed.

August. The Term-day of Aug 28–9 was greatly deranged from 10^h 40′ P. M. Gott. M. T. to 8^h A. M., and small perturbations were experienced for 4 or 5 hours after this time. The whole range of the magnetic declination amounted to 61′. Once between 6^h 40′ and 7^h 20′ A. M. the change of declination exceeded 43′ in 27 minutes. The other days observed in August were still.

September 21–2. The sweep during this day was 45′.5. The disturbances on the days observed in this month have been already discussed at length. They were distinguished more by number than extent of arc.

October. The October curves were not entirely free from disturbances though they are all comprehended, in their widest excursions, in a zone of 22′ in breadth.

November. The three days of this month have some perturbations, but none deserving especial notice.

December. Two of the curves observed in this month were disturbed considerably; yet, the whole range does not surpass 28′.5.

1841.

January. The curves observed in this month were generally regular. On the 26th of January, between 4^h and 5^h A. M. Gott. M. T., a small disturbance was felt amounting to 17′.

February. General perturbations spread over the three days of this month, particularly observed at night. Those of greatest extent occurred on the Term-day, February 26–7, amounting in one case to 16′ of arc in 15 minutes of time. In addition to these extracts from the records of the different months, Table II. contains a column showing the extremes of the Magnetometer every day when complete observations were made.

The theory of the Aurora Borealis which has of late years found most favor with men of science supposes it to have some connexion with Electricity and Magnetism. It is important to investigate this subject further and see whether there be any and what relation between this brilliant appearance of the heavens and the derangements of the magnetic declination. For this purpose a careful record has been kept of all the Auroral appearances that have been

noticed at the Cambridge Observatory; some of the most remarkable presented themselves at times when the regular observations on the Declination Magnetometer were in progress; and pains have been taken whenever it was practicable to watch the instrument on all other occasions when the heavens gave signs of preparation for such an exhibition. Annexed is a list of those which were displayed on a grand scale.

April 24–5. Slight Aurora.

May 28–9. Remarkable Aurora. An arch was formed, at $2^h\,39'$, A. M. Gott. M. T., running as nearly as could be ascertained at right angles to the magnetic meridian. A crown began to form at $4^h\,24'$. Its position was referred to α Cor. Borealis which was then on the meridian. As it was nearly at the same altitude of $74^\circ\,52'$ and to the west of the meridian, it could not have been far from the magnetic Pole. Shortly after this the arch was broken up and the northern sky covered with pulsations of light.

May 29–30. Brilliant Aurora. The auroral arch was first seen at $2^h\,32'$ A. M. Gott. M. T., extending from a point nearly east to within a few degrees of the western horizon. The light was intense. The apex of the arch was situated 20° at first, and at $2^h\,42'$, 30° south of the zenith. After this time, the light became broken and scattered, flying from east to west. This arch was entirely detached from the main body of the Aurora and resembled a streamer. In the north there was a diffused light but very bright; and swift flashes towards the zenith. At $3^h\,59'$ a large meteor was seen in the north, 20° high, descending towards the northwest.

June 26–7. About $2^h\,36'$ A. M. Gott. M. T., an Aurora was seen at the North, of a white diffused light. At $6^h\,20'$, the Aurora assumed a dull appearance, with dark wane intermixed. At 7^h A. M., the Aurora became more active, and some streamers were seen. The needle was slightly affected at this time.

July 4–5. Between 5^h 28′ and 5^h 34′ Gott. M. T., bright diffused Northern Lights; occasionally long streamers; wane clouds near the northern horizon; Magnetometer quiet.

July 29–30. At 2^h 45′ A. M. Gott. M. T. (July 30) an auroral arch was formed 7° above the horizon and very still. At 9^h 40′ it began its motion up towards the zenith; rose to the altitude of 30°. At 3^h 54′, the Aurora had ceased. The light was dull during the whole time.

August 19–20. A steady auroral arch was observed. It was double and the altitude of its apex at 3^h 54′ A. M. Gott. M. T. (August 20) was 7° or 8°; its color was dull white. This Aurora continued till 4^h, and at 4^h 11′ the Northern Lights had entirely disappeared.

August 28–9. An auroral arch appeared running from east to west, of intense brightness and diffused, but without streamers. Apex nearly on the meridian and altitude 45° at 2^h 30′ A. M. Gott. M. T. At 3^h 20′ streamers shot up 60° from the horizon; the altitude of its highest part was about 76° 43′, as found from its place among the stars.

October 22–3. Between 1^h and 2^h A. M. Gott. M. T. an Aurora of a steady blue light was first perceived; it afterwards became brighter and whiter, the altitude was 3°; wane clouds below. At 5^h 20′, the Aurora was low.

November 30. At 3^h 24′ A. M. Gott. M. T., an Aurora was seen of white diffused light. No regular arch was formed. The Magnetometer was quiet.

It appears from this abstract of the records that the days most distinguished for auroral appearances are just those on which the declination of the magnetic meridian experienced the most extraordinary derangements. This was the case on May 29–30 and August

28–9. Unfortunately the Magnetometer was not watched on the night of May 28–9. By referring to Plate IV. it will be seen that the Declination instrument was subject to more than ordinary influences on the 22d of October between 0^h M. and 6^h A. M. Gott. M. T. The observers on the remarkable days of May and August describe the motions of the Magnetometer as peculiar in the highest degree. It was often checked in the midst of its vibration and suddenly forced back in the opposite direction; and this took place with such frequency at certain seasons as to give to the motion the appearance of jerks or sharp twitches. No correspondence was noticed between the time of maximum magnetic disturbance and the formation of the auroral crown. But it was sometimes supposed from successful comparisons in the phases of the different phenomena that the instrument gave intimation by some strange motion of the most signal changes in the Aurora. The display of May and August was as fine as any that has been witnessed for several years and we should not omit to state that on these occasions the Declination Magnetometer at Cambridge made the boldest sweep of the scale. As both these days happened to be Term-days the opportunity was improved at other magnetic Observatories of watching the coincidence between the auroral appearances and the perturbations, and the report is generally uniform from all. Plate II. which represents the May-term diurnal curve of declination offers a specimen of the extraordinary disturbances to which we refer and the time of them may be compared with the phases of the Aurora which are contained in the record for that day. The excursion at *g* was so great that it was found necessary to curtail it on the Plate; but the extent will be readily seen from remarking that it reached to 71.4 on the scale, 47′.2 of which were traversed in 11 minutes of time. An Aurora was seen on the same night at

Philadelphia, New Haven and at Toronto, U. C. A description of its appearance at New Haven may be seen in Silliman's Journal, No. I. Vol. XXXIX.* Where facilities existed for making the observations it was discovered to be accompanied with similar effects upon the magnetic declination as were felt at Cambridge. The Magnetometer at Philadelphia experienced great derangements, although the limits were less, not exceeding 55′.8. The influence which an Aurora exerts upon the earth's magnetism reaches as far and wide as the appearance itself; and probably the intensity of the effect is proportional to the brilliancy of the display. The greatest disturbance of the Magnetometer at Philadelphia was, as at Cambridge, between 4^h and 5^h A. M. Gott. M. T. The deflection of the instrument at Cambridge amounted to about 57 minutes, and the extremes were separated by little more than 2 hours. Lieutenant Riddell informs us that at Toronto the arc traversed was 1° 59′, which was never equalled, and approached but once on a similar occasion. We also learn from him that an Aurora was noticed at Greenwich, Great Britain, on the same day; but he adds, that the disturbances there and at Toronto were very different.

Such full information is not possessed in regard to the Aurora of August 28–9. It is evident from the observations that the Magnetometer at Cambridge was more affected on that day than ever before, the whole change of declination amounting to 61′. At Toronto, where the Aurora was also seen, the disturbances were equally surprising and produced an oscillation of 1° 33′ in declination. The greatest amount of derangement at Cambridge was as follows:

* See also the Journal of the Franklin Institute for June, 1840, which contains some observations made upon it at Southwick, Mass.

At 1^h 25′ A. M., Gott. M. T., the reading of the scale was	111.9	
		Range of 52′.4 East in 1^h 10′.
" 2^h 35′ " " " " "	164.3	
		Range of 52′.9 West in 1 hour.
" 3^h 35′ " " " " "	111.4	

Again, at 5^h 20′ A. M., Gott. M. T., the reading of the scale was	108.5	
		Range of 47′.6 East in 25 minutes.
" 5^h 45′ " " " " "	156.1	
		Range of 52′.4 West in 1 hour.
" 6^h 45′ " " " " "	103.7	

During the first of these periods, the Aurora reached its culmination of splendor; between 5^h and 7^h it was faint and near the horizon. It does not appear from an examination of the May or August Term-day that the maximum agitation of the Magnetometer coincides in time with the greatest brilliancy of the heavens. In May, it had not accumulated its action when the Aurora began to decline; and in August, although it accompanied the display it continued with undiminished energy one or two hours after that had passed away. The most rapid motion of the bar was from 5^h 20′ to 5^h 45′, being equal to 47′6. in 25 minutes. This is nothing strange; but might be expected from the time which all the forces of nature consume in communicating themselves to bodies and penetrating large masses so as to overcome their inertia. More exact and frequent observations will doubtless conduct to a better knowledge of a connexion which is now so undeniable and yet so imperfectly understood. If observers are careful to note the times at which the chief phases of the Aurora are witnessed and its position among the stars and, where they have the opportunity, the simultaneous variations of the Magnetometer we may not despair of elucidating these two classes of intricate and interlaced facts; the

Aurora and the irregular perturbations of the magnetic meridian. It must not be inferred that other causes do not exist, in coöperation with the auroral phenomena, to derange violently the earth's magnetism. According to Ampere's theory of currents a large fund of such derangements must be deposited under the crust of the earth. The equilibrium although permanently stable must be subject to constant fluctuations. Theory supplies the reason and observation asserts the fact. Many of the small daily derangements have no apparent relation to the Aurora; and in regard to the magnificent strides of the Magnetometer it cannot be told which is cause and which is effect. If further search shall prove that an Aurora never fails to attend a great disturbance we may conclude that the Aurora itself is seldom displayed in the daytime. For the remarkable changes of declination almost always begin during the night and seldom continue into the next day. If, however, an unseasonable Aurora should occasionally arise we may be able to perceive indications of its presence from the magnetic perturbations, although its light were eclipsed by the brightness of the sun.

So far we have attended to relative only and not to absolute declinations. The former are sufficient when the object is to find the times of maxima and minima, the daily range and the diurnal curve. But it sometimes becomes necessary to know the absolute declination, so that the process will now be described of referring any reading of the scale to its absolute value. It is clear that if the absolute value of one reading can be ascertained that of all the rest is known at once. It is convenient to have the absolute declination always referred to the same number of the scale; we will suppose this number to be, therefore, 100. To find then the absolute declination corresponding to 100 of the scale we proceed thus: the Variation-transit with which the Gauss Magnetometer is observed

is placed firmly on the table and then the line of collimation is adjusted in the meridian by means of Polaris and the large Transit-instrument; a section having been made in the roof for this purpose. The azimuthal circle is then read off. The circle is now turned until the line of collimation coincides with the direction of the magnetic meridian, as indicated by the needle that accompanies the *Variation-transit.* At the same moment the circle is read off again and the scale is noted through the telescope. The difference of readings from the azimuthal circle will indicate the angle which the magnet makes at that time with the astronomical meridian, and the reading from the scale shows to what number on it this absolute variation corresponds. Now since according to their arrangement on the scale at Cambridge an increase of numbers implies a decrease of declination, we readily find the absolute declination of 100 of the scale by adding or subtracting as the case requires the difference between 100 and the reading at the time. This will be easily understood from the following example:

The azimuthal reading by Polaris, June 21, at 8 P. M. Gott. M. T. - - - - - -	= 310° 34′ 40″.
The azimuthal reading at the Coincidence of the Needle - - - - - - -	= 301° 15′ 30″.
When the reading of the scale through the telescope was 100,835, the absolute declination -	= 9° 19′ 10″.
The absolute declination at 100 of the scale -	= 9° 20′ 00″.

As it may not always be possible to take an astronomical observation on account of the state of the atmosphere, the azimuthal angle between some fixed mark and the true meridian is read off and the position of the magnetic meridian determined by reference to this. Thus it appears, June 25th, that a certain mark on Gore Hall, which

has been previously found to be 38° 11′ west of the north, reads on the circle

	272° 23′ 30″
Adding its azimuth or . .	38 11
The azimuthal reading of the true meridian	= 310° 34′ 30
The azimuthal reading at the Coincidence of Needle . . .	= 301° 14′ 50
Absolute variation for 102.966 of the scale	= 9° 19′ 40
" " for 100. .	= 9 22 38

The absolute variation corresponding to 100 of the scale being known, the real values of all the lower numbers are found from it by adding and of all the higher numbers by subtracting the difference between them and 100. Here we suppose of course that all the readings on the scale are made in the same position of the telescope as the one by which the original absolute variation was determined. To secure this condition, when the observations begin, the azimuthal circle must be firmly clamped at some place which is considered the fixed reading for this period; and the vernier should be occasionally examined to see that the instrument has not been deranged. The absolute declination thus obtained cannot be relied on within so small a limit of error as that to which the changes of declination are subject. The chief uncertainty attaches to the coincidence of the needle with the line of collimation. Several readings repeated in succession are likely to vary three or four minutes so that their mean is only an approximation to the truth. Hence the difficulty of ascertaining the yearly change of declination which is so small as to be partially masked under accidental errors. If the feet of the Variation-transit were firmly secured to some durable foundation, the yearly variation might be found at once from the scale as we now find the daily ones. In this case the fixed reading should

not be altered from one set of observations to another. Hereafter, as the observations will be made with Lloyd's Declination Magnetometer and a fixed telescope, we shall not be subjected to this inconvenience.

For greater accuracy, the absolute variation assigned to 100 of the scale for any period should not depend upon a single set of readings. But the process which has been described for finding the real value of any part of the scale should be repeated as often as possible during the days of regular observations. Thus we have:

June 21 at 8^h 0′ P. M. Gott. M. T., the absolute variation .	= 9° 20′ 00″	at 100 of the scale.
June 22 at 11^h 15′ A. M. " "	= 9 21 14	" "
" 25 " 12 22 P. M. " "	= 9 22 34	" "
" 28 " 9 35 " " "	= 9 24 25	" "
" 29 " 3 26 " " "	= 9 21 44	" "
" " " 12 00 M. " "	= 9 20 53	" "
" 30 " 11 25 P. M. " "	= 9 18 29	" "
July 1 " 0 45 " " "	= 9 18 57	" "
" " " 11 25 " " "	= 9 20 36	" "
Mean for June	= 9 20 59	" "
October 20 at 7^h 30′ P. M. " "	= 9 18 15	" "
" 21 " 9 40 " " "	= 9 18 29	" "
" 22 " 10 5 " " "	= 9 16 40	" "
" 23 " 8 15 " " "	= 9 19 11	" "
" 24 " 2 10 " " "	= 9 16 58	" "
" 24 " 10 10 " " "	= 9 16 54	" "
" 25 " 2 45 " " "	= 9 15 56	" "
Mean for October . . .	= 9 17 29	" "

We now pass from the absolute value in declination of 100 of the scale to the absolute declination in this way. If the absolute varia-

tion for any single moment were desired, we should readily find it by adding or subtracting as the case required the difference between the reading on the scale and 100 to the absolute value of 100. But when speaking of the absolute variation we generally intend some mean value which is the representative of that element for a whole day or month or perhaps a longer period. We should certainly miss of this mean variation if we adopted the regular maximum or minimum reading of the scale or that of any extraordinary stride which may have been observed during the period. No single mark on the scale can lead to any thing more than a momentary expression of this element. The mean of the daily maximum and minimum limits of the scale or more accurately the mean of all the observations furnishes a mark from which some durable value of absolute declination may be derived. Now the mean of all the observations belonging to the 10 days of June is 103′.603 of the scale:

Hence the variation sought is . . . . . 9° 20′ 59″ — 3′ 36″
or 9° 17′ 23″.

Again, the mean of the observations made during the 5 days of October is 98′.838 ; hence the variation is 9° 17′ 29″ + 1′ 10″
or 9° 18′ 39″.

The mean absolute Declination from June to November, 1840, may be considered . . . = 9° 18′ 01″.

The following Table shows the variation of the needle at Cambridge and in the vicinity from the period of the earliest observations:

Cambridge	1708	9° 0′ W.	Cambridge	1788	6° 38′ W.
"	1742	8 0 "	Boston	1793	6 30 "
"	1757	7 20 "	Salem	1805	5 57 "
"	1761	7 14 "	"	1808	5 20 "
"	1763	7 0 "	"	1810	6 22 "
"	1780	7 2 "	Cambridge	1810	7 30 "
Beverly	1781	7 2 "	"	1835	8 51 "
Cambridge	1782	6 46 "	"	1840	9 18 "
"	1783	6 52 "			

As there can be no great difference between the variation for Boston and Cambridge* we infer from the Table that from 1708 to 1793 the declination diminished at the mean annual rate of 1′.8; and that from 1810 to 1840 it increased at the mean annual rate of 3′.6. It is probable that the change in direction took place between 1793 and 1810 at Cambridge; whatever was the cause it does not appear to have affected instantaneously remote places. Dr. Bowditch who made the observations at Salem in 1805, 1808 and 1810 supposed that the first two were smaller than they ought to be on account of instrumental errors. But I think that this was not the whole cause. The change in direction, if it had not already happened in 1810, came soon after. Now, on the assumption that it was after 1810, the mean annual rate of decrease at Salem (considering the observations at Beverly as comparable with those made at Salem) would be only 1′.3. This is smaller than the decrease appears to have been on the average. I incline to think, therefore, that the minimum declination really occurred during the period of Dr. Bowditch's observations, and that the differences which he attributed wholly to defects in the instruments were partly caused by this very circumstance. The value of the variation at Beverly in 1781 was obtained from the mean of 7 partial means which did not differ more than 6 minutes from each other. The variation at Salem in 1810 was the mean of 5125 observations. Confidence may accordingly be placed in both of these values; and consequently in the mean annual decrease of 1′.3 that results from them. Again,

* The following values of the latitude and longitude are taken from the American Almanac for 1840.

	Latitude.	Longitude.
Boston	42° 21′	71° 4′
Cambridge	42 22	71 8
Salem	42 31	70 53

the variation at Boston in 1793 is the mean of 1644 observations. The variation at Cambridge in 1782 is deduced from frequent observations at different hours on 127 days of that year. Allowing a reasonable error to beset the value at 1708, we may suppose that the number of years from which the rate of annual decrease is derived secures it from any large error. The same reliance may reasonably be placed in the determination of the rate of increase. The fact then is very remarkable that since the passage from a direct to a retrograde motion the rate of the annual change of variation has so materially altered. Assuming that the mean annual rate of decrease was 1′.8,* the time of the change interpolated into the observations would be 1807; and this in the absence of better authority may be regarded as its date for Cambridge.

Another element of the Earth's Magnetism on which some attention has been bestowed at Cambridge is the Dip. All the methods of observing the Dip are extremely defective and do not admit of so great a degree of accuracy as the Declination instruments. The Dipping-needles of Gambey and Troughton and Simms are preferable to any other direct method of measuring absolute Dip. But two of the best Dipping-needles may vary 15′ and more in the determination of this element for the same time. This difficulty suggested to Gauss the idea of expressing the Dip as a function of the horizontal and vertical components of the magnetic intensity. This led to the invention of his Bifilar Magnetometer and the Horizontal Force Magnetometer of Lloyd. Professor Lloyd has added to

* In most cases of this kind, the rate varies about the times of maximum and minimum as the time, reckoned from these points respectively ; so that the value of the element is in proportion to the square of this time. But in the present instance, the simple supposition we have made in the text conforms best to the observations.

these another extremely delicate instrument by which *variations* of the Vertical Force may be observed. Consequently, with his two instruments the *changes* of Dip may be calculated to a close approximation, though the absolute Dip remains unaffected by all the improvements. In addition to the usual corrections applied to observations made with the dipping-needle the precaution should be taken of observing the inclination in different azimuths and deducing the true dip from every set at right angles to each other. Mr. Fox has invented a dipping-needle Deflector which gives the dip and intensity by a statical principle and Mr. Lloyd has applied the same principle to the simultaneous determination of the dip and intensity. Observations with the Vertical Force Magnetometer commenced with us on the Term-day of March, 1841; but they do not enter into the plan of the present paper and any further notice of them or of the instruments is deferred till we come to the description of the new Magnetic Observatory. The Dip has been observed directly at Cambridge and the vicinity during the last four years at irregular intervals. The Dipping-needles used were of the best construction, one of them made by Gambey, and the other, now in the possession of Major Graham, obtained from Troughton & Simms. The following Table gives the results with some old observations on the same element:

Place.	Date.	Dip.
Cambridge	1780	69°51′
"	1782	69 41
"	1783	69 41
Mean for	1782	69 44
	Lat.	Long.
Cambridge	42°22	71°8
Dorchester	42 19	71 4

		Gambey two needles.	Troughton and Simms one needle.	Means.
Dorchester	June 8	74° 20.3	74° 25.6	74° 23′
Cambridge	" 10	74 17.1		74 17.1
" *	"	74 20.1		74 20.1
"	June 22	74 24.7		74 24.7
"	"	74 14.1		74 14.1
"	Sept^{r}. 6 1841	74 22.5	74 11.5	74 17
"	May 9	74 35.5		74 35.1
Mean for	1840			74 21.6

* This observation was made by Professor Loomis.

Supposing that the inclination has been on the increase since 1782, its mean annual rate would be equal to 4.′5. It is thought that the inclination is decreasing at present in the United States as it has long been in Great Britain and on the continent. Professor Loomis assigns the rate for this country at 1.′8 yearly. If this be so, we observe the same great difference in the rate of increase and decrease of the inclination as of the declination. In either case it is equally inexplicable. The want is now felt of systematic observations of the dip in order to eliminate regular and irregular changes of this element and obtain a true mean for a given period. The general scheme of magnetic observations has not failed to provide for this, as we shall see further on. So far as the subject has been investigated, the dip does not appear to pass through such a uniform succession of positions daily as the declination. Its value often changes suddenly and to the amount of a degree and a half although according to Kupffer the regular daily range does not exceed five minutes. As the various observations on the Dip at Cambridge and Dorchester were made with the same needles, the range of 21′ in the values cannot be charged to the needles, and it is too great to come under the *daily* or *annual* variation. Observations made elsewhere show that such irregular disturbances occasionally derange the dip. Moreover the mean value, derived from frequent partial results obtained on different days and different hours of the same day, is still exposed to what may be called a constant error of the needle and which is not eluded by any of the different reversals. Thus out of 8 needles used by Captain James Ross in London, 2 differed 41′ in the values which they gave for the dip; although from 640 to 1000 readings were made with each. We subjoin the following Table drawn up by Quetelet,* which contains the value of the annual diminution of the magnetic inclination at various places:

* Nouveaux Mémoires de l'Académie Royale des Sciences et Belles-Lettres de Bruxelles. Tome XII. 1839.

Paris	3.′7	Stockholm	3.′13
Brussells	3. 4	London	2. 4
Berlin	3. 7	Dublin	2. 3
Turin	3. 5	Christiana	3. 56
Florence	3. 3	Gottingen	3. 05
Milan	3. 87	St. Petersburg	3. 8
Upsal	3. 27		

In 1837, Gauss published his "*Allgemeine Theorie des Erdmagnetismus.*" This was the first attempt to subject the Problem of the Earth's Magnetism to strict mathematical analysis. The solution was embarrassed and complicated, being of the nature of those which had already been performed in determining the Figure of the Earth and the Tides. It required the use of Laplace's celebrated coefficients, a powerful instrument but difficult of management. Besides, it labored under the peculiar disadvantage of not being supplied with sufficient data derived from observation for calculating with precision the value of the constants. The whole developement may be found in the original or translated Memoirs of Gauss and a general idea of the analysis can be obtained from the able Article on Terrestrial Magnetism in the London "Quarterly Review" to which reference has already been made. What is here called a theory makes none or the most general assumptions as to the nature and distribution of magnetism in our planet. The investigation, which is mathematical throughout, depends at last on ascertaining the values of certain constants from observed data. Here the want was felt of a complete series of such as were nearly accurate and strictly comparable. It cannot be entirely relieved until the accomplishment of the present magnetic enterprise. With insufficient data, but the best that the state of science afforded, many of which were obtained through the assistance of the German and Russian Mag-

netic Associations, Gauss calculates on the principle of least squares, which allows more places on the earth to be represented than there are unknown quantities, the values of his coefficients. After passing the formulæ through several new forms, the chief object of which was to make them more simple and to facilitate the application, he brings the three components of the function into the following shape.

X, *Y* and *Z* are the three coördinates of the magnetic force exerted upon a given point of the earth whose longitude is reckoned east from Greenwich. The auxiliary angles A^{I}, A^{II}, &c. B^{I}, B^{II}, &c. C^{I}, C^{II}, &c. depend upon the latitude.

$$X = a^{\circ} + a^{\mathrm{i}} \cos.(\lambda + A^{\mathrm{i}}) + a^{\mathrm{ii}} \cos.(2\lambda + A^{\mathrm{ii}}) + a^{\mathrm{iii}} \cos.(3\lambda + A^{\mathrm{iii}}) + a^{\mathrm{iv}} \cos.(4\lambda + A^{\mathrm{iv}})\ldots$$
$$Y = b^{\mathrm{i}} \cos.(\lambda + B^{\mathrm{i}}) + b^{\mathrm{ii}} \cos.(2\lambda + B^{\mathrm{ii}}) + b^{\mathrm{iii}} \cos.(3\lambda + B^{\mathrm{iii}}) + b^{\mathrm{iv}} \cos.(4\lambda + B^{\mathrm{iv}})\ldots$$
$$Z = c^{\circ} + c^{\mathrm{i}} \cos.(\lambda + C^{\mathrm{i}}) + c^{\mathrm{ii}} \cos.(2\lambda + C^{\mathrm{ii}}) + c^{\mathrm{iii}} \cos.(3\lambda + C^{\mathrm{iii}}) + c^{\mathrm{iv}} \cos.(4\lambda + C^{\mathrm{iv}})\ldots$$

Professor Peirce has calculated the value of *X*, *Y* and *Z* by these formulæ for the Cambridge Observatory, whose longitude is 71° 7′.5 W. and whose latitude is 42° 22′ N. Here $\lambda = 288° \; 52'.5$. The equations give these values for the coefficients and auxiliary angles.

$a^{\circ} = +645.9$	$b^{\circ} = 0$	$c^{\circ} = +1300$
$\log. a^{\mathrm{i}} = 2.29185$	$\log. b^{\mathrm{i}} = 2.23230$	$\log. c^{\mathrm{i}} = 2.36763$
$\log. a^{\mathrm{ii}} = 1.74467$	$\log. b^{\mathrm{ii}} = 2.04629$	$\log. c^{\mathrm{ii}} = 2.19893$
$\log. a^{\mathrm{iii}} = 1.36560$	$\log. b^{\mathrm{iii}} = 1.59317$	$\log. c^{\mathrm{iii}} = 1.62487$
$\log. a^{\mathrm{iv}} = 0.75277$	$\log. b^{\mathrm{iv}} = 0.92425$	$\log. c^{\mathrm{iv}} = 0.88968$
$A^{\mathrm{i}} = 245° \; 55'$	$B^{\mathrm{i}} = 353° \; 17'$	$C^{\mathrm{i}} = 90° \; 34'$
$A^{\mathrm{ii}} = 278 \;\; 42$	$B^{\mathrm{ii}} = 56 \;\; 55$	$C^{\mathrm{ii}} = 157 \;\; 13$
$A^{\mathrm{iii}} = 243 \;\; 31$	$B^{\mathrm{iii}} = 322 \;\; 2.5$	$C^{\mathrm{iii}} = 46 \;\; 19$
$A^{\mathrm{iv}} = 142 \;\; 26$	$B^{\mathrm{iv}} = 232 \;\; 26$	$C^{\mathrm{iv}} = 322 \;\; 26$

then we have:

$\lambda + A^{\mathrm{i}} = 534° \; 47'.5$	$\lambda + B^{\mathrm{i}} = 642° \; 9'.5$	$\lambda + C^{\mathrm{i}} = 379° \; 26'.5$
$2\lambda + A^{\mathrm{ii}} = 856 \;\; 27$	$2\lambda + B^{\mathrm{ii}} = 634 \;\; 30$	$2\lambda + C^{\mathrm{ii}} = 734 \;\; 58$
$3\lambda + A^{\mathrm{iii}} = 1110 \;\; 8.5$	$3\lambda + B^{\mathrm{iii}} = 1188 \;\; 40$	$3\lambda + C^{\mathrm{iii}} = 912 \;\; 56.5$
$4\lambda + A^{\mathrm{iv}} = 1297 \;\; 56$	$4\lambda + B^{\mathrm{iv}} = 1387 \;\; 56$	$4\lambda + C^{\mathrm{iv}} = 1477 \;\; 56$

and consequently:

$$+\,645.\,9 = a^{\circ}$$
$$\log. a^{\mathrm{i}} + \log. \cos.(\lambda + A^{\mathrm{i}}) = 2.29006 = -\,195.01 = a^{\mathrm{i}} \cos.(\lambda + A^{\mathrm{i}})$$
$$\log. a^{\mathrm{ii}} + \log. \cos.(2\lambda + A^{\mathrm{ii}}) = 1.60487 = -\,40.26 = a^{\mathrm{ii}} \cos.(2\lambda + A^{\mathrm{ii}})$$
$$\log. a^{\mathrm{iii}} + \log. \cos.(3\lambda + A^{\mathrm{iii}}) = 1.30251 = +\,20.07 = a^{\mathrm{iii}} \cos.(3\lambda + A^{\mathrm{iii}})$$
$$\log. a^{\mathrm{iv}} + \log. \cos.(4\lambda + A^{\mathrm{iv}}) = .64970 = -\,4.46 = a^{\mathrm{iv}} \cos.(4\lambda + A^{\mathrm{iv}})$$
$$X = 426.20$$

$$\log. b^{i} + \log. \cos. (\lambda + B^{i}) = 1.55579 = + \ 35.96 = b^{i} \cos. (\lambda + B^{i})$$
$$\log. b^{ii} + \log. \cos. (2\lambda + B^{ii}) = \ .95669 = + \ 9.05 = b^{ii} \cos. (2\lambda + B^{ii})$$
$$\log. b^{iii} + \log. \cos. (3\lambda + B^{iii}) = 1.09840 = - \ 12.54 = b^{iii} \cos. (3\lambda + B^{iii})$$
$$\log. b^{iv} + \log. \cos. (4\lambda + B^{iv}) = \ .71294 = + \ 5.16 = b^{iv} \cos. (4\lambda + B^{iv})$$
$$Y = \ 37.6$$
$$+ 300.00 = c^{o}$$
$$\log. c^{i} + \log. \cos. (\lambda + C^{i}) = 2.34214 = + 219.85 = c^{i} \cos. (\lambda + C^{i})$$
$$\log. c^{ii} + \log. \cos. (2\lambda + C^{ii}) = 2.18394 = + 152.74 = c^{ii} \cos. (2\lambda + C^{ii})$$
$$\log. c^{iii} + \log. \cos. (3\lambda + C^{iii}) = 1.61370 = - \ 41.09 = c^{iii} \cos. (3\lambda + C^{iii})$$
$$\log. c^{iv} + \log. \cos. (4\lambda + C^{iv}) = \ .78661 = + \ 6.12 = c^{iv} \cos. (4\lambda + C^{iv})$$
$$Z = \ 1637.6$$

X, Y and Z being thus determined, if we represent the declination by δ, the inclination by i, the total intensity by ψ and the horizontal intensity by w, we have these two formulæ to find δ and w:

$$X = w \cos. \delta, \quad Y = w \sin. \delta.$$

Again;

$$w = \psi \cos. i, \quad Z = \psi \sin. i.$$

from which i and ψ are deduced.

$$\log. Y = 1.57519$$
$$\log. X = 2.62961 \qquad \log. X = 2.62961$$
$$\frac{Y}{X} = \text{tang. } \delta = 8.94558 \qquad \text{sec. } \delta = 0.00170$$
$$\delta = 5^{\circ} 4. \qquad 2.63131 = X \text{ sec. } \delta = w = 427.9$$
$$\log. Z = 3.21421 \qquad \log. Z = 3.21421$$
$$\log. \text{cosec. } i = 0.01433 \qquad \text{tang. } i = 0.58290 = \frac{Z}{w}$$
$$\psi = 1692.5 = 3.22854 = Z \text{ cosec. } i \qquad i = 75^{\circ} 22'$$

After dividing the numbers which represent the Horizontal and Total Intensity by 1000 to reduce them to the arbitrary unit in common use, we have the following values of the elements for 1837, calculated according to Gauss' formulæ.

	Computed.	Observed.	Difference.
The Declination	= 5° 4′	9° 9′	4° 5′
The Dip	= 75 22	74 22	1 00
The Horizontal Intensity	= 0.4279		
The Total Intensity	= 1.6925		

We are now able to add one more to the list of 99 places for which Gauss has compared the computed and observed values of the elements. The difference which appears in all cases between the two is produced by several causes. The observations are not cotemporaneous: and they are vitiated by accidental errors and the strange anomalies of the magnetic force. The coefficients which depend upon the grouping of the observed values must suffer from the same influences; and hence the computed places by no fault of the theory are involved in uncertainty. In some cases the two errors may balance each other; at other times they will conspire to produce a great difference. Thus we explain those considerable discrepancies which occasionally appear between the results of observation and calculation. So far as declination is concerned, Cambridge suffers particularly from these causes; there are only 3 out of the 97 places for which Gauss has made the computation where the difference is so great between the computed and observed element. In these instances, it amounts respectively to 5° 45′, 4° 42′ and 5° 15′. In regard to inclination the case is more favorable, as there are 40 places in Gauss' catalogue where the difference is greater than at Cambridge; the maximum difference being 4° 38′, or 5 times that of the latter place. Out of the 98 places for which the declination has now been calculated the difference is plus in 52 instances and minus in 46; and out of 100 for which the inclination has been computed the difference is plus 66 times and minus 34 times. This is satisfactory proof that the error proceeds from the observations and not from the theory. Before sentence can be fairly pronounced upon the latter, better observations must be possessed for comparison and the determination of the arbitrary coefficients. It is especially to be desired that cotemporaneous observations of great accuracy should be made in every quarter of the globe, that the calculated values of the coefficients may

be general and impartial. Until this is done we cannot expect that the theory, however complete in itself, will give correct expressions of the elements for all parts of the earth. Thus we explain the large difference between the calculated and observed declination for Cambridge and a few other places. We must however never lose sight of the fact that remarkable local disturbances may sometimes derange the observed value of the element so as to leave still a few cases of unusual discrepance. Part VII. of the "Scientific Memoirs," contains maps of the lines of declination and inclination on the globe for 1838, drawn by Gauss according to his theory. In Silliman's American Journal, No. 2 of 1838, is a Chart of Professor Loomis which presents both these classes of lines as they crossed the United States in 1840; they were projected from a collection of all the observations that had been made in the country, after they were reduced to the same time. A comparison of the observed and empirical lines exhibits sufficient agreement to satisfy us of the general correctness of Gauss' theory in its application to this Western Continent. Mr. Loomis remarks, in a paper published in the Philosophical Transactions of Philadelphia,* that the same dip is found in a higher latitude in the western than in the eastern states. By recurring to Gauss' Map of the lines of inclination we notice the same singularity in the empirical lines. So also on Gauss' Map of declination, the lines which are far apart in Europe are convergent in the northern states as they approach the Magnetic Pole. We can readily conceive therefore that an error in the value of the coefficients, which should hardly be felt in one place, may be magnified into great importance at the other. We dismiss this interesting discussion with the confident hope that the simultaneous and extensive

* Transactions of the American Philosophical Society. Vol. VII, New Series. Part I. Philadelphia. 1840.

observations of the magnetic elements which are now in progress will soon relieve the author of the theory from the embarrassments to which the want of accurate data subjected him; and enable him to predict with certainty concerning the magnetic state of any part of the globe, though it has never been approached by man.

We shall close this communication with a brief description of the new Magnetic Observatory at Cambridge. The buildings which have been erected for this purpose are represented on the right hand of Plate I. They connect with the observer's house at the northwest corner through a covered passage. Their shape as seen on the ground plan was determined by the positions required for instruments which they were to contain. The impossibility of ascertaining the dip with accuracy has caused it to be dropped as one of the primitive Elements of Terrestrial Magnetism and the horizontal and vertical forces have been substituted in its place. The three instruments in use at the Magnetic Observatories established by the Royal Society, and recommended to all the allies, are the Declination Magnetometer, and the Horizontal and Vertical Force Magnetometers. The first two are inventions of Professor Lloyd, and correspond in their objects and part of their construction to the Gauss Declination Magnetometer and his Bifilar Magetometer. Instead of the mirror, and the scale to be reflected from it, these bars are furnished with two sliding pieces, one at each end. That farthest from the observer contains a finely divided scale of glass; the other, an achromatic lens. The distances of the two are so arranged that the scale shall be in the focus of the lens. It is evident that the apparatus thus adjusted forms a moving collimator. The scale is carried by the bar in all its changes of position and, being read off by a fixed telescope at a suitable distance, records the variations of magnetic declination. It is extremely easy to pass from the read-

ings of the scale to absolute values. It is only necessary to find the azimuth of the line of collimation of the telescope by a Variation-transit, and then adding or subtracting the difference between the former and a fixed point of the scale, determined by observation, we readily convert every observation into absolute declination. In this respect the instrument of Lloyd is preferable to the Gauss Magnetometer, where the passage from marks on the scale to their corresponding absolute values is difficult and uncertain. A more minute description of Lloyd's apparatus may be found in the Report of the Royal Society to which we have made frequent reference. It was first proposed that the place of the bar should be marked at three successive excursions and the position determined by the familiar formula $\frac{1}{4}(a + 2\,b + c)$; where a, b and c express the three readings. But a circular was issued to the Magnetic Observatories, under date of January 15, 1841, and signed by Professor Lloyd, recommending that the method of observing the Declination and Horizontal Intensity Magnetometers be so far modified as that, instead of the three successive readings just mentioned, they should be taken at the times $T—t$, T, and $T+t$, of which T is the appointed epoch of observation and t the mean time of vibration of the magnet. This is returning essentially to the principle of Gauss, which gives the position of the bar for the precise moment required, and which we should think to be generally superior, whenever the length of the arc of vibration admits of it, to the method of observing three successive excursions. To recur now to the Plate; b is the place of the Declination Magnetometer, g and g windows to allow the light to pass in so as to be reflected strongly on the scale; e is the place of the fixed telescope; a is a pillar which supports the Variation-transit. This instrument can be adjusted in the meridian by independent observations of the stars, through a section in the roof at

h, or more easily by inverting the Transit at *B* and using it as a collimator. If the Variation-transit be directed to the mid-wire of the large Transit, so that while its line of collimation falls behind the latter it also intersects the mark on Blue Hill, then we know that it is in the same meridian line as the Transit, and by turning it over to the North and reading off the azimuth of the line *a e* we find the variation of the fixed telescope and, consequently, the absolute value of every reading that is made with it. We pass now to the Horizontal Force Magnetometer which differs from the Bifilar Magnetometer of Gauss only in employing a movable collimator instead of the mirror. The principle of either instrument is easily explained. A magnetized bar is suspended by a double wire, attached to two points near its centre at a definite distance apart, which remains the same through their whole length. The cap at the top from which the suspension is made is then turned until the torsion suffices to bring the bar round at right angles to the magnetic meridian. The horizontal component of the magnetic force of course tends to bring it back to the magnetic meridian, and therefore its mean value is measured by the mean torsion. But as the torsion remains nearly constant at the same angle, any change in the horizontal force is indicated by the motion of the bar to the one side or the other of the perpendicular direction. This small variation from a mean position is observed in the same way precisely as the variations of declination in the first instrument; the change of horizontal intensity is a simple function of this small arc and very easily determined. When the absolute horizontal intensity is required, it is found by the method which Gauss employs with his Bifilar Magnetometer. *c* is the place of the Horizontal Force instrument. *f* is the place of the fixed telescope whose position at right angles to the magnetic meridian is readily adjusted by the Variation-transit at *a*.

Hence, all the readings of this instrument can be readily converted into absolute determinations by applying the variation with the proper sign as a correction to the mean absolute value. Again, d represents the position of the Vertical Force Magnetometer. It consists of a magnetized bar resting by knife-edges on agate planes and loaded so as to be horizontal at the average value of the Vertical Force. It is evident that any change in the amount of this force will be indicated by a motion of the arms of the lever one way or another. Any motion of this sort is observed by fixed microscopes with micrometer wires in front of each end of the bar, the double reading securing greater accuracy. Two cross wires in a hollow circle on each extremity of the bar determine for the eye its axis; and the changes of the Vertical Force are a function of the variations of this axis from its mean horizontal position. Both the Horizontal and Vertical Force instruments are furnished with thermometers, and corrections for temperature are applied in the reduction of the observations to a definite unit. Thus we have the means of observing the three approved elements of the earth's magnetism. In regard to the Vertical Force, however, no way that is not open to practical objections has been devised of obtaining its absolute value. It is recommended, therefore, to obtain it indirectly from the formula $V = H$ tang. i where H represents the horizontal intensity and i the inclination. Thus, we are still subject to the inconvenience of observing the dip of the needle with the common dipping apparatus for absolute determinations of itself and the Vertical Force. The last Circular to the Magnetic Observatories advises that observations be made on the dip *Tuesdays in the forenoon and Fridays in the afternoon.* Various modes of observing this instrument are in use, and the best result is probably obtained by a combination of all of them.

The buildings which contain these instruments are made of wood with copper nails. Iron has been carefully excluded from every part. In order that the corrections for temperature may be small they are furnished with a soapstone stove, having a copper funnel.* The instruments rest upon blocks of red sandstone, which are firmly set on the ground, insulated from the vibrations of the floor, and known to be free from magnetic influence. It is of the first importance to secure the several Magnetometers from mutual interference. They are all too distant from the Gauss Magnetometer at C to give or receive any disturbance in that quarter. The mutual action of two magnets diminishes as the cube of the distance, and greater security has been placed in this mode of reducing it than more complex ones. Thus the distance from b to c is 36 feet 9 inches; from b to d is 36 feet 2 inches; from c to d 40 feet 6 inches. The distances of the fixed telescopes e and f from b and c respectively are 7 feet; from a to b it is 30 feet, and the width of the building is 6 feet. Biot, Gauss and Lloyd have investigated the problem of the mutual action of a system of magnets; and positions have been found for a limited number of bars in which the disturbance should be nothing or constant; in the latter case, a simple correction applied to all the observations or which might be made at once in the construction of the scale, if the arrangement were previously known, is all that is necessary. Out of several combinations of this kind for three magnets, which the general theory discloses, we have selected the one recommended by Weber. The line $a\ b$ of course is the direction of the magnetic meridian; $a\ c$ is perpendicular to it; then the point c is so selected that the an-

* In the magnetic Observatory at Munich, the instruments are placed in a room, 13 feet below the surface of the ground, where the temperature varies but little through the year.

gle which the line *b c* makes with the magnetic meridian at *b* may be equal to 35° (theoretically it should be 35° 15′ 52″.) Now, we are sure that the mean place of the declination instrument is not affected by the disturbance of *c* upon *b*, since it acts in the direction of the magnetic meridian. But the deviations from it will be affected by a constant error for which a correction must be applied. Again, the Horizontal Force instrument is practically affected only in regard to the divisions of the scale. The tangential part of the disturbance tends to move the needle from its transverse position but this is prevented by the suspension and enters unperceived into the calculation of the absolute value of the element. Again the angle which the line *b d* makes with the magnetic meridian is also 35°; so that *b* is affected by *d* in the same manner as by *c*. The action which *b* would exert upon *d*, being in a horizontal direction, can have no influence in deranging *d*, which admits only of motion in a vertical direction.

These three instruments have been in adjustment two months, and regular observations were made with them on the Term-days of March and April, 1841; and will hereafter be continued. The same observer, by constant attention, is able to tend the three instruments at once. Thus, if the time were 10 P. M. Gott. M. T., *b* would first be observed at 0^m; then *c* at $2^m\ 30^s$, then *b* again at 5^m, then *d* at $7^m\ 30^s$, then *b* a third time at 10^m, and *c* a second time at $12^m\ 30^s$, *b* a fourth time at 15^m, and *d* a second time at $17^m\ 30^s$. In this way, which is continued during the whole period of observation, we have one observation of the declination every 5 minutes, and one of the Horizontal and Vertical forces every 10 minutes. On the March Term-day, which was the time when the transition was made from the Gauss to Lloyd's Magnetometer, both declination instruments were observed in order to see how far they were com-

parable. At first sight the two curves with a general agreement exhibited some alarming discrepancies; but these have been referred to the stretching of the suspension threads of the new instrument, and are not likely to recur again. Another opportunity will be taken of comparing the two instruments together after that of Lloyd has attained its proper bearings. Fig. 2 of Plate II. represents one hour's observation with these Declination Magnetometers. As the apparatus for all the Magnetic Observatories is from the hands of the same artist the observations will be eminently comparable. A few years of such observations conducted on a systematic and uniform plan will avail more in solving the intricate problem of Terrestrial Magnetism and reducing it to a theory, than the whole mass of scattered and disorderly data that have accumulated since the days of Gilbert.

TABLE I.

Gottingen Time, reckoned from Mean Noon.	1840. March. 27/28	May. 29/30	June. 24/25	July. 24/25	Aug. 28/29	Sept. 23/24	Oct. 21/22	Nov. 27/28	Dec. 23/24	1841. Jan. 20/21	Feb. 26/27	March. 24/25
X— 0	106.9	109.3	104.1	100.3	116.5	111.0	96.0	96.7	91.1	91.0	93.1	92.7
5	107.1	109.4		100.2	116.5	111.4	96.0	96.8	90.3	90.6	92.7	95.1
10	107.3	107.1		100.1	116.2	111.4	96.2	96.5	90.1	91.3	92.0	94.1
15	107.5	106.8		99.9	115.0	110.8	96.4	96.2	89.8	92.9	91.2	92.3
20	107.9	108.9	103.8	100.1	116.4	111.8	96.4	95.8	88.9	94.9	91.1	91.4
25	108.3	108 9		100.2	117.3	112.5	95.9	95.7	89.1	95.2	92.0	92.4
30	108.9	111.6		100.1	122.4	114.6	96.1	95.9	89.2	94.5	91.3	91.6
35	109.6	106.5		100.2	126.9	116.3	98.8	96.4	89.7	94.3	92.0	90.8
40	110.2	109.2	103.7	100.3	134.1	117.9	101.7	96.2	90.0	94.1	92.3	91.5
45	110.4	111.7		100.5	134.9	117.5	104.5	96.0	90.5	93.6	93.3	92.2
50	110.7	112.0		100.6	131.7	114.7	102.1	97.1	90.1	93.2	93.3	94.2
55	110.7	113.5		100.7	129.7	112.4	100.5	97.2	90.3	93.2	92.8	94.0
XI— 0	110.5	111.6	103.2	100.7	127.4	110.6	99.0	98.3	91.1	93.3	91.8	93.3
5	110.3	106.0		100.7	125.1	109.0	97.1	98.8	91.9	93.4	90.2	92.4
10	110.6	110.1		100.8	123.4	106.1	98.5	99.6	93.6	93.4	89.8	94.3
15	111.0	111.3		100.4	122.4	104.8	99.7	99.4	95.0	93.7	90.0	93.7
20	110.9	106.0	103.8	100.2	119.7	103.9	100.7	99.2	94.7	93.6	90.2	91.9
25	110.9	123.4		99.9	117.0	103.2	99.7	99.3	94.7	93.3	89.5	91.7
30	110.9	101.3		99.8	114.9	102.5	99.1	99.4	91.8	93.5	89.4	92.7
35	111.1	117.5		100.2	114.9	100.8	99.6	100.4	92.1	93.3	89.4	93.1
40	111.1	116.7	103.9	100.8	116.0	99.3	99.2	101.2	93.2	93.5	89.4	92.1
45	110.7	109.4		100.9	117.5	98.6	99.1	101.5	95.2	93.7	90.4	94.2
50	110.8	107.7		101.0	120.2	98.4	97.7	101.6	94.0	93.9	91.3	96.3
55	110.9	112.1		101.0	118.1	98.1	97.9	101.3	93.3	94.0	91.7	96.7
XII— 0	111.4	113.3	103.4	100.8	116.9	98.4	98.2	100.1	92.0	94.1	91.8	98.1
5	111.7	117.1		100.6	115.7	98.5	99.7	99.8	92.6	94.3	91.3	97.6
10	111.6	116.5		101.0	114.5	99.1	99.7	99.7	93.4	94.7	90.6	94.9
15	111.2	113.5		100.8	112.6	98.7	100.5	99.7	93.5	94.9	90.7	92.5
20	111.1	109.6	103.7	100.8	110.5	98.7	101.5	99.7	94.0	95.1	91.7	91.7
25	111.0	106.7		100.7	110.3	98.7	101.9	100.4	94.7	95.2	92.5	92.6
30	111.0	105.6		100.5	111.1	99.4	101.7	101.0	93.5	95.3	92.0	98.6
35	111.1	108.1		100.4	112.2	98.9	101.9	101.3	92 9	95.2	91.2	107.5
40	111.2	110.3	103.7	105.3	112.9	98.8	104.2	101.6	93.0	95.1	89.3	107.4
45	111.5	110.7		101.7	113.6	98.8	107.3	100.8	93.6	95.0	91.6	108.0
50	111.8	110.6		102.4	114.1	98.7	108.4	101.6	94.4	94.8	95.3	105.9
55	112.1	111.1		103.4	113.5	98.8	108·5	100.9	96.6	94.7	104.8	102.8
XIII— 0	112.4	113.1	103.2	103.3	114.5	99.5	106.6	101.5	102.3	94.8	103.6	104.8
5	112.6	113.5		102.4	114.1	99.1	106.1	101.6	103.4	95.0	104.1	104.6
10	112.7	113.4		101.2	114.2	100.6	106.4	101.7	103.9	95.4	104.5	103.5
15	112.9	116.5		99.9	115.1	102.2	105.4	101.8	102.5	95.7	105.6	101.1
20	112.8	115.7	103.5	99.2	113.8	103.5	105.5	102.2	101.5	95.9	104.1	101.4
25	112.5	122.3		99.0	111.9	105.3	105.2	97.2	99.9	96.5	103.2	101.2
30	112.4	122.6		98.6	113.3	104.9	104.4	101.8	102.3	96.7	101.3	102.0
35	113.0	122.7		98.7	115.6	105.5	104.0	102.2	103.9	96.8	98.8	101.8
40	113.5	124.3	104.0	98.9	117.0	109.6	103.3	101.2	102.3	96.9	96.1	101.4
45	113.8	123.1		98.7	116.8	109.6	102.9	101.1	99.5	97.2	96 3	100.5
50	113.6	118.4		98.7	116.7	109.3	102.7	100.2	100.2	97.2	96.4	99.5
55	112.8	121.8		98.3	117.1	107.1	101.7	100.6	100.9	96.9	97.6	99.7
XIV— 0	112 5	122.1	103.2	98.8	118.5	105.2	100.9	100.7	97.5	95.8	97.8	100.0
5		123.2		99.1	121.0	105 2	101.1	101.8	93.2	95.6	97.7	101.5
10	113.0	123·9		99.2	123.5	106.0	101.6	100.7	92 5	95.9	97.6	102.7
15	112.9	124.1		99.3	129.8	105.0	101.8	100.9	90.1	96.0	97.4	103.0
20	112.5	122.8	102.1	99 1	143.1	104.1	101.1	100.7	94.0	96.1	98.3	102 6
25	112 6	118 4		99 5	153.7	105.3	100.6	101.2	95.7	95 9	98.3	101.0
30	113.3	113.5		99.6	162 3	105.7	100.9	101.0	95.4	95.9	98.0	100.5
35	114.2	113.9		99.7	164 4	104.2	101.7	100.9	94.5	96.1	98.1	100.3
40	114.9	116.7	101.0	99.6	164.0	103 4	102.3	100.7	96.8	96.4	97.9	100.0
45	115.7	114.6		99.6	153.9	103.0	103 2	100.5	98.7	96.4	98.5	99.5
50	116.3	111.5		99.8	145.1	102.2	103.6	101.7	100.3	96.7	98.3	100.4
55	116.6			100.0	142.6	101.6	101.6	100.6	100.7	96.7	98.4	99.9

TABLE I.—CONTINUED.

Gottingen Time, reckoned from Mean Noon.	1840. March. $\frac{27}{28}$	May. $\frac{29}{30}$	June. $\frac{24}{25}$	July. $\frac{24}{25}$	Aug. $\frac{28}{29}$	Sept. $\frac{23}{24}$	Oct. $\frac{21}{22}$	Nov. $\frac{27}{28}$	Dec. $\frac{23}{24}$	1841. Jan. $\frac{20}{21}$	Feb. $\frac{26}{27}$	March. $\frac{24}{25}$
XV— 0	117.5	108.7	101.9	100.0	140.3	102.2	101.9	101.3	98.3	97.1	100.0	100.7
5	118.7	113.6		99.8	138.0	102.7	99.2	101.5	99.2	98.2	101.7	100.6
10	118.6	115.6			143.9	101.7	98.4	101.2	98.2	100.0	103.2	99.9
15	119.0	118.6			139.9	100.8	98.4	101.6	101.3	102.0	102.0	99.1
20	117.5	116.0	101.9		137.0	100.7	100.0	101.8	103.9	103.2	101.6	98.8
25	117.1	117.1		100.6	130.9	100.8	102.4	101.7	103.6	103.5	95.9	98.0
30	116.3	113.4			124.8	101.2	103.5	99.7	103.0	102.5	93.4	98.9
35	115.4	110.0			111.5	100.3	103.3	100.9	101.6	101.1	94.4	100.0
40	115.0	101.8	103.9	101.7	120.4	97.9	102.7	100.5	100.6	99.3	99.4	102.1
45	114.1	96.3			127.7	97.4	102.2	99.8	102.0	97.7	99.7	102.7
50	113.9	101.7			129.8	98.3	101.9	100.9	102.5	97.9	100.9	101.6
55	113.8	114.4			129.2	100.0	106.1	100.9	100.7	97.1	106.9	100.1
XVI— 0	113.7	96.7	105.1	102.0	125.8	101.5	107.3	100.5	100.0	97.5	106.7	97.4
5	113.0	71.2			127.1	103.6	105.3	99.9	99.3	97.1	105.9	97.1
10	112.4	70.2			127.8	102.2	103.4	99.9	98.6	96.8	101.7	96.9
15	113.1	75.9			113.8	100.5	99.9	100.5	97.8	95.7	100.3	97.3
20	112.7	77.6	105.2	101.8	110.9	100.2	92.6	101.4	98.0	95.2	99.7	99.1
25	112.0	90.7			116.9	101.0	88.2	100.3	98.5	94.9	100.5	98.7
30	111.7	95.9			120.9	101.4	88.0	100.8	97.8	94.8	102.1	98.7
35	111.7	100.4			115.4	100.5	93.9	100.9	97.4	94.9	98.7	98.3
40	111.9	95.4	108.1	102.4	113.8	100.1	96.4	99.7	97.3	95.0	96.7	95.5
45	112.3	80.8			115.7	100.2	98.4	100.1	97.1	95.2	96.0	94.3
50	112.3	98.1			119.4	101.1	98.1	100.4	97.1	95.3	97.5	94.9
55	112.2	103.9			124.7	101.4	99.0	99.7	97.4	95.2	96.7	95.2
XVII— 0	112.0	97.7	106.2	102.2	129.1	103.3	98.7	100.2	97.6	95.0	97.0	94.7
5	111.9	95.7	106.8		125.5	103.9	97.7	99.9	98.5	94.8	97.3	93.4
10	112.1	112.4	107.5		119.6	103.9	99.7	99.8	99.2	95.0	95.9	93.7
15	112.2	121.2	108.0		112.7	104.1	102.9	99.1	99.6	95.9	97.0	92.2
20	112.2	116.6	108.2	102.5	108.5	103.8	104.9	99.3	99.6	95.3	96.2	93.4
25	112.5	106.0	108.2		111.4	102.9	105.0	99.2	99.4	95.3	96.6	93.5
30	111.6	104.9	108.2		115.3	102.1	104.2	99.3	99.2	95.1	96.2	94.3
35	109.6	116.4	108.0		156.1	102.8	103.1	99.3	98.8	95.0	96.7	94.2
40	107.8	191.4	107.7	101.9	137.5	103.8	102.5	99.3	98.9	95.0	96.0	96.1
45	107.7	117.3	107.5		137.0	104.4	102.3	99.4	98.7	95.0	97.1	96.9
50	107.2	119.4	107.3		136.2	104.0	102.6	99.1	98.6	95.0	96.6	96.2
55	108.1	119.1	107.2		118.2	103.2	102.1	98.9	98.7	95.2	95.8	97.0
XVIII— 0	109.3	123.4	107.3	101.4	122.0	103.2	101.4	98.6	98.5	95.2	95.7	95.4
5	110.3	121.9			140.7	102.3	101.2	99.1	99.3	95.2	94.1	95.2
10	111.1	119.2			138.5	101.5	100.9	98.6	99.3	95.2	94.3	95.2
15	111.7	118.2			128.7	100.8	101.1	98.3	99.7	95.2	95.4	93.1
20	112.5	121.9	107.5	102.0	121.0	101.2	101.0	99.4	99.5	95.4	96.1	91.3
25	112.3	118.2			122.5	101.9	100.9	99.4	97.3	95.4	95.6	89.7
30	111.6	114.9			128.6	102.7	100.9	99.8	93.7	95.2	95.7	91.1
35	111.1	111.3			126.2	101.6	101.6	98.9	92.7	95.2	95.9	91.7
40	110.4	105.9	107.4	101.3	108.0	99.6	101.6	99.7	91.7	95.3	96.0	92.6
45	111.6	101.0			103.7	99.5	100.3	99.5	89.7	95.2	96.6	93.2
50	111.3	96.0			108.0	100.1	101.2	98.9	89.3	95.0	95.7	92.3
55	111.4	94.4			114.0	101.4	101.8	99.0	90.7	95.4	95.1	92.1
XIX— 0	111.3	91.4	107.9	101.6	117.5	102.0	100.2	99.1	93.2	95.6	95.0	93.1
5	110.7	87.9			127.2	101.0	100.4	99.2	95.4	95.9	96.1	92.7
10	110.5	90.9			146.5	100.5	100.8	98.7	96.4	95.9	95.3	92.6
15	111.0	95.7			141.5	100.5	101.1	98.6	96.4	95.9	92.7	93.6
20	110.7	100.1	108.0	101.8	135.5	100.4	101.1	98.7	97.2	96.1	91.8	92.5
25	111.3	102.2			132.7	99.6	101.5	98.6	97.2	96.2	91.6	93.5
30	111.5	104.7			131.2	99.9	102.2	98.8	96.6	96.1	92.1	94.6
35	112.2	110.1			128.5	101.0	103.0	99.1	97.0	96.1	92.5	93.3
40	113.3	111.8	108.3	101.7	118.0	101.0	103.3	99.3	96.3	96.2	92.6	94.1
45	112.9	115.3			121.1	101.5	103.7	99.0	96.8	96.5	91.8	92.5
50	112.9	117.1			123.5	101.5	103.3	99.4	97.0	96.4	93.2	93.7
55	113.2	117.5			121.6	102.7	103.5	99.4	97.4	96.4	93.2	93.8

TABLE I. — CONTINUED.

Gottingen Time, reckoned from Mean Noon.	1840. March. 27/28	May. 29/30	June 24/25	July. 24/25	Aug. 28/29	Sept. 23/24	Oct. 21/22	Nov. 27/28	Dec. 23/24	1841. Jan. 20/21	Feb. 26/27	March. 24/25
XX— 0	113.4	117.4	108.3	101.8	117.1	103.5	103.2	98.9	97.3	96.4	94.5	93.9
5	113.4	117.1			117.9	103.7	101.3	99.7	97.5	96.1	94.7	92 8
10	113.9	116.7			122.5	103.5	100.9	99.6	97.1	96.3	94.5	97.3
15	113.8	116.1			123.0	104.5	100.5	99.0	96.6	96 3	95.2	92.3
20	113.5	118.5	108.5	102.2	123.0	104.9	98.2	100.7	97.0	96.6	94.9	93 5
25	113.6	118.6			123 6	105.2	97.1	99.5	97.8	96.5	95.1	93.1
30	113 5	121.9			123.7	105.3	95.8	99.6	97.6	96.6	94.6	92.5
35	113.2	120.9			126.4	105.1	95.7	99.4	97.1	96.6	95.2	92.2
40	113.1	118.8	108.6	101.7	126.9	105.1	94.9	98.8	97 3	96.6	95.0	94.3
45	113 0	118.8			127.9	105.4	94.3	98.9	98.3	96.1	95.2	94.3
50	113.1	117.7			129 6	106 1	93.3	99.1	97.8	96 0	95 3	93.8
55	113.0	116.1			128.5	105.9	92.4	99.1	97.3	95.8	95.7	94.3
XXI— 0	113.0	114.7	108.6	101.7	127.0	105.9	91.7	99.5	97.2	95.8	94.9	93.5
5	113.0	114.5			129.2	105.1	92.8	99.7	97.1	96.0	94.1	93.5
10	113.0	114 1			131 7	104.0	94.3	99.6	96.8	95 9	94.1	92.9
15	113 2	113.9			129.4	103 0	96.0	99.8	97.0	95.9	94.4	91.2
20	113 7	113 9	109.0	102.1	130.7	102.2	96.6	100.5	97.6	95 7	92 7	90.0
25	114.0	113.5			130.4	101.0	98 4	99.3	97.8	95.6	92.2	89.1
30	114.2	114 4			130.2	100.3	98.9	100.4	97.5	95 9	92 0	89.5
35	114.3	113.8			131.7	100.2	99.4	101.0	97.9	96.0	92 9	89.2
40	114.0	113.5	109.2	102.9	131.0	99.6	100.1	99.6	97.9	96.0	93.0	88.6
45	113.9	113.4			131.3	99 4	101.7	100.3	97.8	96.1	93.9	89.0
50	113.7	112.5			128.9	97.9	101.2	100.5	97.7	96.3	94.4	91.1
55	113.4	111.7			128.5	97.1	101.1	100.2	97.7	96.1	94.2	90.8
XXII— 0	113.2	111.3	109.0	102.8	129.5	97.9	100.9	100.6	97.5	96.3	95 1	93.6
5	112.9	112 6			130.6	98.1	100.7	101.0	97.7	96 3	95.6	91.4
10	113 1	107.8			130.1	97.9	100.5	100.6	98.3	96.2	95.2	91.5
15	113.5	113.2			129.3	97.2	100.8	100.2	99.1	96 3	95.8	93.6
20	113.8	114.2	109.2	103.5	131.8	96.4	100.9	102.2	100.1	96 2	96.2	92.9
25	114.1	115.0			130.6	95.0	101.1	100.2	99.5	96.1	96.8	94.1
30	114.3	112.0			129.0	94.0	101.2	101.9	98.7	96 2	96.9	94 7
35	114 5	115 0			127.5	92.9	101.1	102.6	96.9	96 3	96.8	94.4
40	114.5	114.5	109.7	103.6	128.2	91·1	101 0	101.2	95.9	96.2	96.3	94.2
45	114 3	113.6			128.2	89 5	101.0	101.9	96.1	96.3	96 8	95.0
50	114.3	113.4			127 6	87.2	101.3	101.4	96.5	96.3	97.3	94.8
55	114.2	111.5			127.0	87.0	101.3	102.2	96.8	96.4	97.8	95.6
XXIII— 0	114.0	112.7	110.2	103.7	128.2	88.4	101.3	100.7	96.5	96.3	97.3	95.4
5	114.5	111.8			130.0	91.2	101.2	98.6	96.9	96.3	97.6	95 7
10	114.8	110.9			129.2	93.0	101.4	100.1	96 5	96.2	97 6	95.2
15	114.8	110 5			130 9	95.6	101.3	99.6	95.4	96.1	97.6	95 7
20	115.0	110.4	110.3	104.3	132.0	95.2	101.4	99.0	94.9	96 2	97.6	96.2
25	114.7	111 0			133 8	95.7	101.7	98.8	94.9	96.4	97.5	97 0
30	115.0	110.8			132.2	96.8	101.6	101.7	95 7	96 2	98 0	97.6
35	115 1	111.1			131.1	96.2	101.7	101 7	96.1	96.5	98.7	98.1
40	114 7	111.2	110.6	105.5	130.5	95.8	101.6	101.2	95.6	96.2	98.2	98.5
45	114.7	112 1		105.4	132.0	95 0	101.8	100.1	95.4	96.4	97 9	98.4
50	114.6	112.7			133 8	95.1	101 9	102.0	95.1	96 6	98 0	98.4
55	114.8	112.8			132.9	93.6	102.2	100.7	95.4	96.1	97.9	98.2
XXIV— 0	114 6	110.8	110 5	105.5	133.3	94.5	102 3	101.0	95.7	96 2	97.8	98.5
5	114.6	111.8	110.5		134.4	94.5	101.3	101.1	95.6	96·2	97.8	98.3
10	115.0	112.3			134.2	95.1	101 9	101.1	96.7	96.4	98 0	98.5
15	115.2	110.2			134.8	94.8	102.4	100·9	98.2	96 4	97.9	98.5
20	115.2	111 4	110.5	105.0	134.6	92.9	102.4	102.5	98 1	96 4	97.5	98.0
25	115.6	111 0			135,2	91 7	102 4	99 5	97.7	96 5	97 8	98.3
30	115.6	112 5			135.2	90·9	102.6	100.9	96.9	96.5	97.9	98 6
35	115 3	113.1			135.8	89.8	102.5	102 0	96 6	96.6	97.9	98.6
40	115.2	113 0	110.3	105.0	136 0	90 5	102.8	103.1	96.6	96 6	97.7	98.9
45	115 2	113 4			135.5	90.9	102 9	102.0	97.6	96 7	97.9	99.0
50	115 5	114.6			135.5	91.2	102.8	102 4	98.4	97.0	98.4	99.2
55	116.1	113.9			135.9	91.7	103.1	102·2	99.0	97.0	98.2	99.3

TABLE I.—CONTINUED.

Gottingen Time, reckoned from Mean Noon.	1840. March. 27/28	May. 29/30	June. 24/25	July. 24/25	Aug. 28/29	Sept. 23/24	Oct. 21/22	Nov. 27/28	Dec. 23/24	1841. Jan. 20/21	Feb. 26/27	March. 24/25
I— 0	115 7	113.5	109.4	104.8	136.5	90.3	103.0	102.5	99.4	97.2	98.6	100.0
5	115.2	112.0			135.9	90.7	103.5	101.5	100.3	97.3	98.4	100.0
10	116.0	112.5			135.3	92.6	103.6	101.2	100.5	97.2	98.8	99.9
15	116.4	111.9			135.0	92.4	103.6	101.1	100.0	97.3	98.9	99.8
20	117.4	111.4	108.1	103.1	135.7	93.4	102.5	101.7	99.4	97.6	98.9	99.7
25	116.5	110.4			134.5	95.4	103.5	102.0	99.7	97.8	99.2	99.4
30	117.1	109.2			133.6	97.2	103.5	102·0	101.5	97.8	99.6	99.8
35	117 3	108.8			132.6	97.8	103.6	102.5	100.0	97.9	99.8	100.1
40	117.0	108.7	107.2	102.0	131.2	99.2	103.6	102.2	99.5	97.8	99.9	99.8
45	116.7	108.9			130.8	100.7	103.3	101.5	98.0	97.8	100.0	100.2
50	116.7	108.1			130.8	101 6	103.4	101·5	98.1	97.9	99.5	100.1
55	116.6	107.7			130.5	101.7	103.3	101·3	99.6	98.0	99.3	99.7
II— 0	117.0	107.0	107.4	101.3	129.9	101.6	104.3	101.7	99.2	97.5	99.5	100.6
5	116.7	105.6			128.2	99.6	102.9	102.6	98.8	98.1	98.9	99.9
10	116.6				129.0	99.7	103.8	103.7	99.9	98.3	98.7	99.9
15	116.2	107.5			128.6	98.0	103.3	103.9	99.8	97.9	98.5	99.3
20	115.9	108.5	107.0	101.6	128.0	99.8	103.3	103.5	100.9	97.9	98.2	98.7
25	115.6	107.1			127.1	99.7	103.3	103.3	100.6	98.2	97.9	99.5
30	115.6	105.4			126.1	101.5	104.1	102 3	99.3	98.7	98.5	99.2
35	114.9	103.6			125.3	101.1	104.0	101.8	98.0	98.6	98.7	99.7
40	114.8	104 2	106.5	102.7	125.7	100.4	103.4	102.1	98.0	98.4	98.4	99.6
45	114.5	103.9			124.2	99.4	102.7	101.3	97.6	98.3	98.4	99.4
50	114.5	102.9			125.0	99.3	102.6	101.5	98.6	98.4	98.4	98.9
55	114.7	103.4			123.5	97.2	102.2	101.2	100.3	98.1	98.6	98.7
III— 0	114.1	105.1	105.8	103.3	123.3	97.7	101.3	99.9	97.9	98.3	98.4	98.7
5	114.0	102.1			122.3	96.1	101.0	100 3	95.7	98.0	98.6	98.4
10	113.9	101.9			121.9	94.1	100.3	100.9	96.0	97.9	98.6	98 7
15	113.7	101.9			121.9	94.7	100.1	101.3	96.2	98.3	98.3	98.6
20	113.3	102.0	105.9	101.9	121.4	95.5	99.0	100.1	97.1	98.0	98.2	98.7
25	113.6	101.9			121.2	94.8	98.5	99.6	96.7	97.3	98.2	98.5
30	113.4	101.9			121.5	93.8	97.4	100.1	97.3	97.7	97.7	98.7
35	113.3	102.4			121.2	93.2	96.4	99.9	97.6	97.6	97.8	97.7
40	112.3		105.8	101.2	121.2	93.4	97.2	100.1	97.4	97.5	97.2	98.4
45	112.2				120 6	94.6	98.1	100.3	96.7	97.5	97.1	98.4
50	111.9				119.7	95.1	97.6	98.7	96.7	97.5	96.9	98.4
55	111.4				119.7	95.0	97.2	98.8	95.9	97.0	97.3	98.1
IV— 0	110.6	103.4	105.7	100.9	119.7	95 6	97.2	98.6	96.1	96.7	96.7	98.3
5	109.4	103.5			119 3	94 6	96.8	98.6	96.0	96.9	96.9	98.2
10	108.9				119.4	95.4	95.7	98.3	97.1	97.6	96.5	98.0
15	108.4	100.2			119.4	94.7	94.9	98.1	96.3	96 5	96.2	98.1
20	108 1		105.5	101.5	119.0	94.2	95.0	98.4	95.7	96.6	95.8	97 8
25	107.9				119.8	93.7	95.1	97.6	96.3	96.8	95.5	97.6
30	107.5	101.1			118.9	92.4	94.9	97.5	96.7	96.5	95.0	97.4
35	107.1				118.7	92.6	95.2	97.2	96.5	96·2	94.9	97.3
40	106.5		105.6	101.6	118.9	93.3	95.2	97.2	96.8	96.2	94.7	97.0
45	106.3	101.7			118.0	95.9	95.0	96.7	96.6	96.3	94.6	96 8
50	106.1				117.2	96.5	93 8	97.0	96.5	96.2	94.3	96.5
55	105.9				116.9	96.7	93.7	97.3	96.5	96.1	93.8	96.3
V— 0	105.8	102 0	105.4	101.4	116.7	96.3	93.6	97.6	96.0	96.1	93.6	96.0
5	105.8			101.5	116.9	96.9	93.5		95.9	96 1	93.7	95 8
10	105.9				117.0	97.8	93.4		96.4	95.8	93.7	95.6
15	105.9	101.0			115.8	98.4	93.4		96.2	95.9	93.1	95.4
20	106.0	102.0	105.0	101.0	115.4	98.3	93 6		96.0	96.4	92 6	95.1
25	105.8					97.8	93 6		95.7	95.9	93.1	95.1
30	105.8	102.0			115.0	98.0	93.9	97.9	85.7	95.7	93.1	95.0
35	105.9				115.1	98.1	94.1	97.5	95.3	95.5	92.8	94.6
40	105.8		104.1	101.4	114.8	98.2	94.0	97.5	95.4	95 2	93.2	94.5
45	105 7	102.2			114.8	98 6	94.6	97.3	94.6	94.9	92.8	94.2
50	105.8	101.7			114.8	98 8	95.0	97.4	95.0	94.4	92.5	93.6
55	105.8	102.0			114.5	98.8	95.1	97.6	94.6	94.2	92.5	93.6

TABLE I. — CONTINUED.

Gottingen Time, reckoned from Mean Noon.	1840. March. 27/28	May. 29/30	June. 24/25	July. 24/25	Aug. 28/29	Sept. 23/24	Oct. 21/22	Nov. 27/28	Dec. 23/24	1841. Jan. 20/21	Feb. 26/27	March. 24/25
VI— 0	105.9	101.8	104.0	100.7	114.4	98.1	94.8	97.3	94.1	93.8	92.3	93.6
5	105.9				114.2	98.1	94.0	97.0	94.3	93.4	91.8	93.5
10	105.7	101.6		95.0	114.4	98.5	94.3	97.2	94.0	93.2	91.8	93.5
15	106.1			99.4	115.0	98.4	94.6	97.6	94.1	92.5	92.2	93.1
20	106.0	101.9	103.5	99.0	114.9	98.5	94.9	97.8	93.9	92.1	91.9	92.8
25	105.8			98.4	115.2	98.5	94.8	97.5	93.3	91.9	91.7	92.5
30	106.4	102.0			114.8	98.8	94.9	96.1	93.2	91.5	91.5	92.5
35	106.2	102.5		98.9	115.1	98.8	96.3	95.4	93.3	91.6	91.6	92.2
40	106.2	102.7	103.0	99.6	115.3	98.6	96 4	94.7	93.3	91.5	91.3	92.4
45	105.0	103.0			115.3	98.1	96.5	95.0	93.6	91.6	91.4	92.2
50	104.9	103.0			115.4	97.5	96.3	94.6	93.2	91.6	91.2	92.2
55	105.0	103.1			115.6	97.8	95.7	95.0	93.0	91.8	91.2	92.3
VII— 0	104.2	103.2	102.1	99 5	115.5	97.9	95.9	95.1	93.1	91.1	91.3	92.3
5	104.1	103.4			115.8	97.7	96.1	95.2	93.7	89.9	91.3	92.2
10	104.1	103.6			115.9	98.1	96.2	95.4	93.6	91.1	91.0	92.1
15	104.2	103.7			115.9	98.1	96.6	95.2	94.3	91.2	91.1	92.1
20	104.3	104.0	101.9	101.0	116.3	98.2	96.6	95.0	94.1	91.7	91.3	92.1
25	104.3	104.1			116.6	98.5	96.3	94.8	93.7	90.8	91.2	92.0
30	104.2	104.0			116.4	98.4	96.1	94.9	93.4	90.3	90.6	92.0
35	104.5	104.0			116.5	98.1	96.2	94.8	93.0	91.4	90.0	91.7
40	104.1	104.3	101.3	99.5	116.6	98.4	95.8	94.8	92.8	91.3	90.0	91.4
45	104.4	104.2			116.3	98.5	95.8	94.8	92.7	91.2	89.6	91.3
50	104.4	104.5			116.2	99.0	95.6	95.1	92.4	91.3	89.6	91.1
55	104 3	105.0			116.3	98.9	95.2	95.4	92.0	90.8	89.7	90.9
VIII— 0	104.2	105.0	101.2	99.3	116.7	99.3	95.2	95.4	91.8	90.4	89.9	91.0
5	104.1	105.2			116.7	100.2	95.2	95.6	92 2	90.2	90.2	91.0
10	104.1	105.9			116.8	100.2	95.1	95.6	92.0	90.3	90.9	90.8
15	104.2	105.6			117.0	100.7	94.9	95.6	92.1	90.1	91.1	90.8
20	104.3	105.5	100.9	98.4	116.9	101.5	94.9	95.7	92.3	90.9	91.2	91.1
25	104·3	105.6			117.2	103.4	94.9	96.0	91.8	90.7	91.2	90.9
30	104.2	105.5			117.1	104.1	94.9	95.7	91.9	90.9	91.4	90.7
35	104·5	105.5			118.6	104.8	94.9	95.8	91.4	90.0	91 5	90.1
40	104.1	106.0	100.9	97.8	118.0	105.7	95.1	95.7	91.6	89.5	91.5	90.0
45	104.4	106.2			116.9	106.2	95.1	95.6	91.7	87.8	91.6	89.9
50	104.4	107.0			117.5	107.1	94.9	95.3	91.7	87.0	91.6	90.0
55	104.3	107.5			117.5	107.6	94.8	94.8	92.5	87.8	91.9	89.9
IX— 0	104.6	107.1	100.4	97.2	117.6	107.4	95.5	94.7	92.6	87.9	91.9	89.9
5	104.9	107.5			117.3	106.0	95.4	95.0	92.5	88.1	91.8	89.9
10	104.7	106.7			117.5	104.8	95.6	95.3	92.4	88.4	92.1	89.8
15	105.3	106.2			117.6	104.1	95.7	95.7	92.5	89.7	92.3	89.8
20	105.4		101.0	98.7	117.8	103.8	96.1	96.0	93.5	91.0	92.2	89.9
25	105.4	107.0			117.4	102.5	96.2	96.6	93.8	91.5	92.4	90.2
30	105.4	108.9			117.5	102.8	96.4	96.8	94.0	90.8	92.3	90.7
35	105.7	107.4			117.3	101.0	96.9	97.2	93.9	92.1	92.4	91.1
40	105.9	108.9	101.0	99.2	117.4	101.0	97.1	97.5	94.0	91.9	92.3	91.3
45	105.8	108.2			117.5	102.1	97.4	97.6	93.7	92.2	92.5	91.5
50	106.1	113.0			117.4	102.5	97.7	98.7	93.9	92.3	92.6	91.6
55	106.6	113.2			117.7	102.6	98.0	98.6	94.0	93.2	92.8	92.1

That part of Table II., which is referred to on page 24, may be found on page 38, where it is introduced for another purpose. The column, containing the greatest daily excursions, which was promised on page 51, has been omitted altogether, as it did not seem to be necessary for a complete view of the subject under discussion.

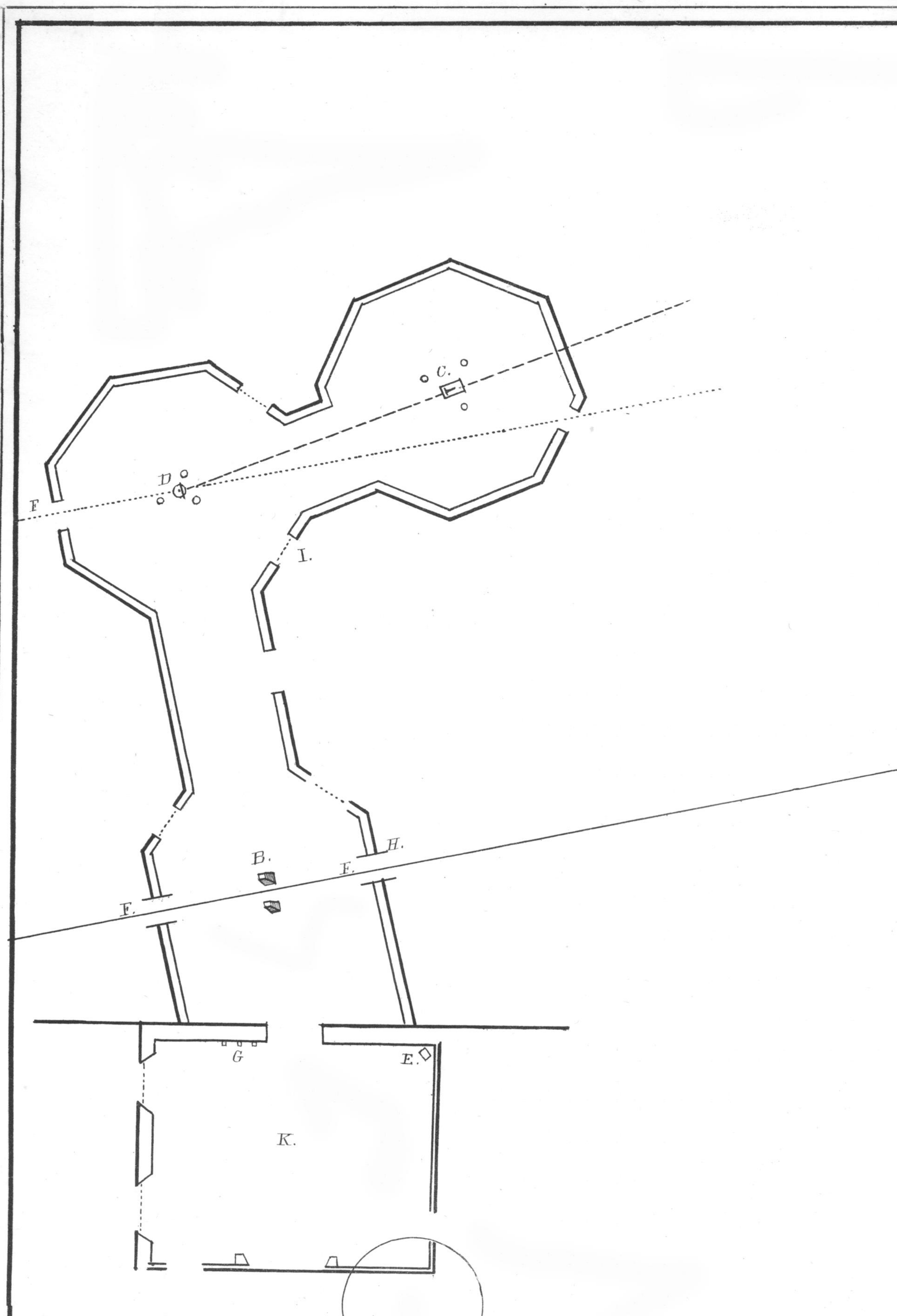
TABLE III.

	June.			August.			September.			October.		
	Computed.	Observed.	Difference.	Computed.	Observed.	Difference.	Computed.	Observed.	Difference.	Computed.	Observed-	Difference.
X— 0	102.57	102.67	— .10	118.00	118.01	— .01	103.95	105.52	—1.57	97.37	97 04	+ .33
20	102.93	103.01	— .08	118.27	118.45	— .18	104.05	107.54	—3.49	97.86	98.41	— .55
40	103.24	103.15	+ .09	118.51	118.95	— .44	104.16	107.16	—3.00	98.34	100.36	—2.02
XI— 0	103.42	103.35	+ .07	118.72	119.22	— .50	104.29	105.45	—1.16	98.80	100.18	—1.38
20	103.65	103.54	+ .11	118.92	119.43	— .51	104.46	106.36	—1.90	99.23	99.29	— .06
40	103.73	103.72	+ .01	119.11	119.47	— .36	104.66	103.81	+ .85	99.63	99.78	— .15
XII— 0	103.72	103 61	+ .11	119.30	119.09	+ .21	104.89	101.39	+3.50	99.98	98 94	+1.04
20	103.63	103.85	— .22	119.49	119.46	+ .03	105.14	100.59	+4.55	100.36	98.72	+1.64
40	103.49	103.71	— .22	119.69	119.23	+ .46	105.38	101.28	+4.10	100.55	101.87	—1.32
XIII— 0	103.26	103 34	— .08	119.90	119.18	+ .72	105.59	104.16	+1.43	100.76	100 62	+ .14
20	103.16	103.45	— .29	120.13	119.35	+ .78	105.74	106.31	— .57	100.92	101.23	— .31
40	103.03	103.12	— .09	120.37	120.15	+ .22	105.83	107.54	—1.71	99.04	101.36	—2.32
XIV— 0	102.97	102.90	+ .07	120.62	120.27	+ .35	105.83	111.59	—5.76	101.11	100.11	+1 00
20	102.99	102 58	+ .41	120.88	119.98	+ .90	105.75	108.57	—2.82	101.13	100 15	+0.98
40	103.12	102.31	+ .81	121.14	121.48	— .34	105.57	106.07	— .50	101.12	101.57	— .45
XV— 0	103.36	103.27	+ .09	121.40	122.24	— .84	105.33	104.98	+ .35	101.06	101.27	— .21
20	103.72	104 28	— .56	121.64	121.59	+ .05	105 02	104.23	+ .79	100.98	100.85	+ .13
40	104.11	104.72	— .61	121.85	122.24	— .39	104.69	102 99	+1.70	100.86	101 76	— .90
XVI— 0	104.58	104.78	— .20	122.08	123.18	—1.15	104.35	103.68	+ .67	100 72	103.37	—2.65
20	105.07	105.46	— .39	122.18	123.29	—1.11	104.04	104 13	— .09	100.54	98 23	+2.31
40	105.55	105.94	— .39	122.29	122.94	— .65	103.77	103.78	— .01	100.34	98.82	+1.52
XVII— 0	105.97	105.76	+ .21	122.35	122.69	— .34	103.56	99.78	+3 78	100.12	100.80	— .68
20	106.31	106 21	+ .10	122.38	122 67	— .29	103.42	104.46	—1.04	99.87	100.89	—1.02
40	106.55	106.20	+ .35	122.39	121.90	+ .49	103.35	102.52	+ .83	99.62	100.24	— .62
XVIII— 0	106.69	106 28	+ .41	122.36	121.25	+1.11	103.35	103.96	— .61	99.36	98.05	+1.31
20	106.72	106 49	+ .23	122.33	120.95	+1.38	103.40	105.33	—1.93	99.10	98 53	+ .57
40	106.66	106.27	+ .39	122·30	121.74	+ .56	103.48	102.52	+ .96	98 84	99 23	— .39
XIX— 0	106.55	106.48	+ .07	122 29	121.90	+ .39	103 57	105.22	—1.65	98 60	98.51	+ .09
20	106.38	106.45	— .07	122.30	122.62	— .32	103.65	104.16	— .51	98.38	98.93	— .55
40	106.24	106 34	— .10	122.36	121.50	+ .86	103.70	104.60	— .90	98.20	99.45	—1.25
XX— 0	106.05	106 95	— .90	122 46	122.35	+ .11	103.71	105.72	—2.01	98 07	98.81	— .74
20	106.15	106 78	— .63	122.63	123.61	— .98	103 67	104.39	— .72	97 99	97.78	+ .21
40	106.23	106.68	— .45	122.86	123.72	— .86	103.58	102.40	+1.18	97.98	97.51	+ .47
XXI— 0	106.46	107.03	— .57	123.14	123.86	— .72	103.45	101.92	+1.53	98 03	95.76	+2.27
20	106.79	106.84	— .05	123 48	123.78	— .30	103.28	104.65	—1.37	98.14	96.98	+1.16
40	107.24	107.20	+ .04	123.87	123.90	— .03	103.12	103 81	— .69	98.33	98.74	— .41
XXII— 0	107.77	107.16	+ .61	124.28	124.47	— .19	102.95	101.47	+1·48	98.58	99 54	— .96
20	108.46	107.68	+ .78	124.70	124.77	— .07	102.79	99.50	+3.29	98.89	99·74	— .85
40	109.06	108.32	+ .74	125.12	124.60	+ .52	102.66	100.80	+1.86	99.24	100.20	— .96
XXIII— 0	109.53	109.02	+ .51	125 50	124.61	+ .89	102 56	104.86	—2.30	99.62	100.53	— .91
20	110.20	109 55	+ .65	125·82	126.11	— .29	102 48	107.79	—5.31	100.00	100 50	— .50
40	110.37	109.86	+ .51	126.07	126.56	— .49	1012.4	103.32	— .91	100.39	99.42	+ .97
XXIV— 0	110.58	110 31	+ .27	126.22	126.18	+ .04	102 34	103.35	—1.01	100.74	99.71	+1.03
20	110.63	110.53	+ .10	126.25	126.08	+ .17	102 24	102.46	— .22	101.04	99.80	+1.24
40	110.50	110.19	+ .31	126.15	125.70	+ .45	102.10	100.72	+1.38	101.28	100 94	+ .34

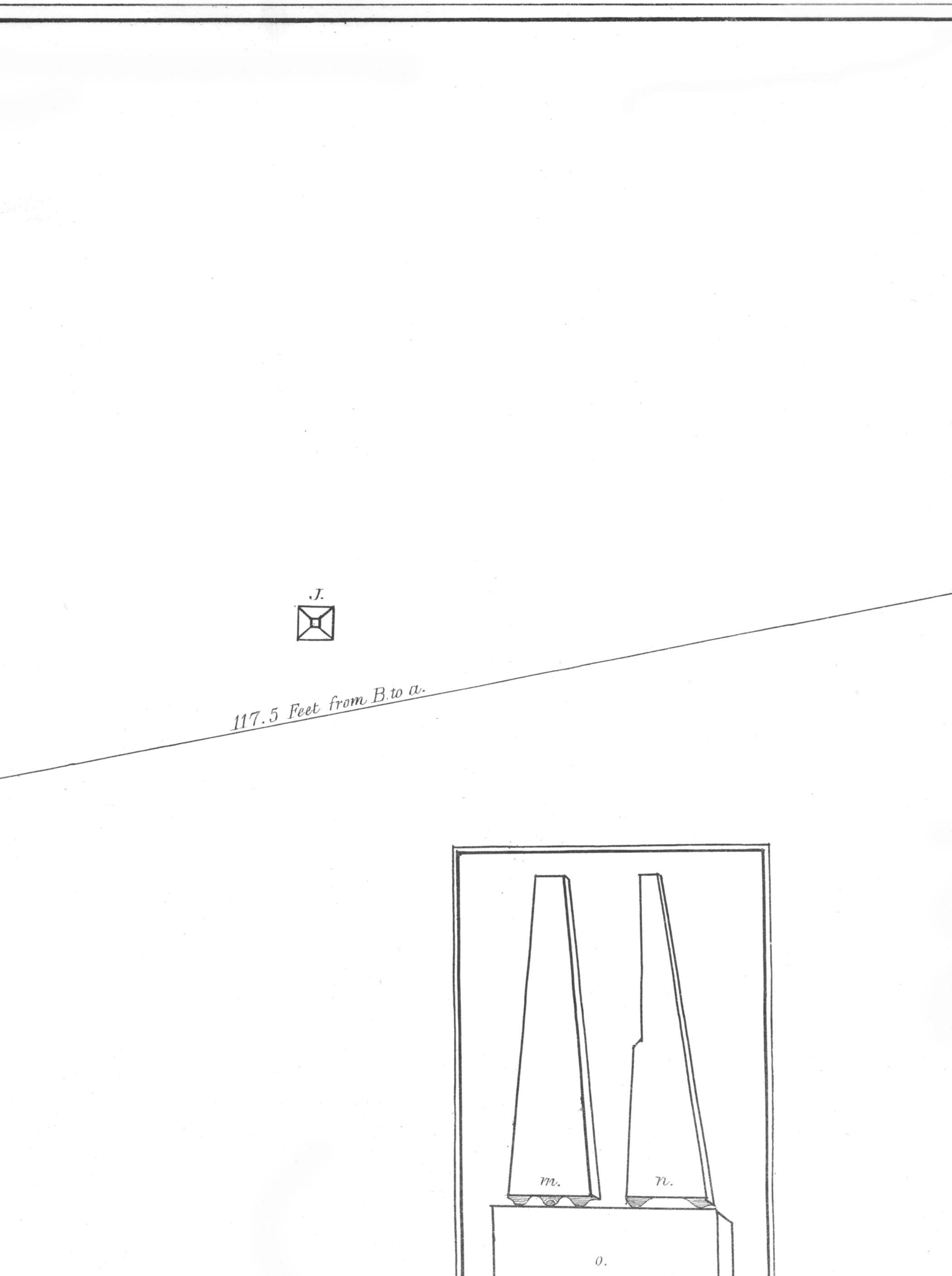
TABLE III. — CONTINUED.

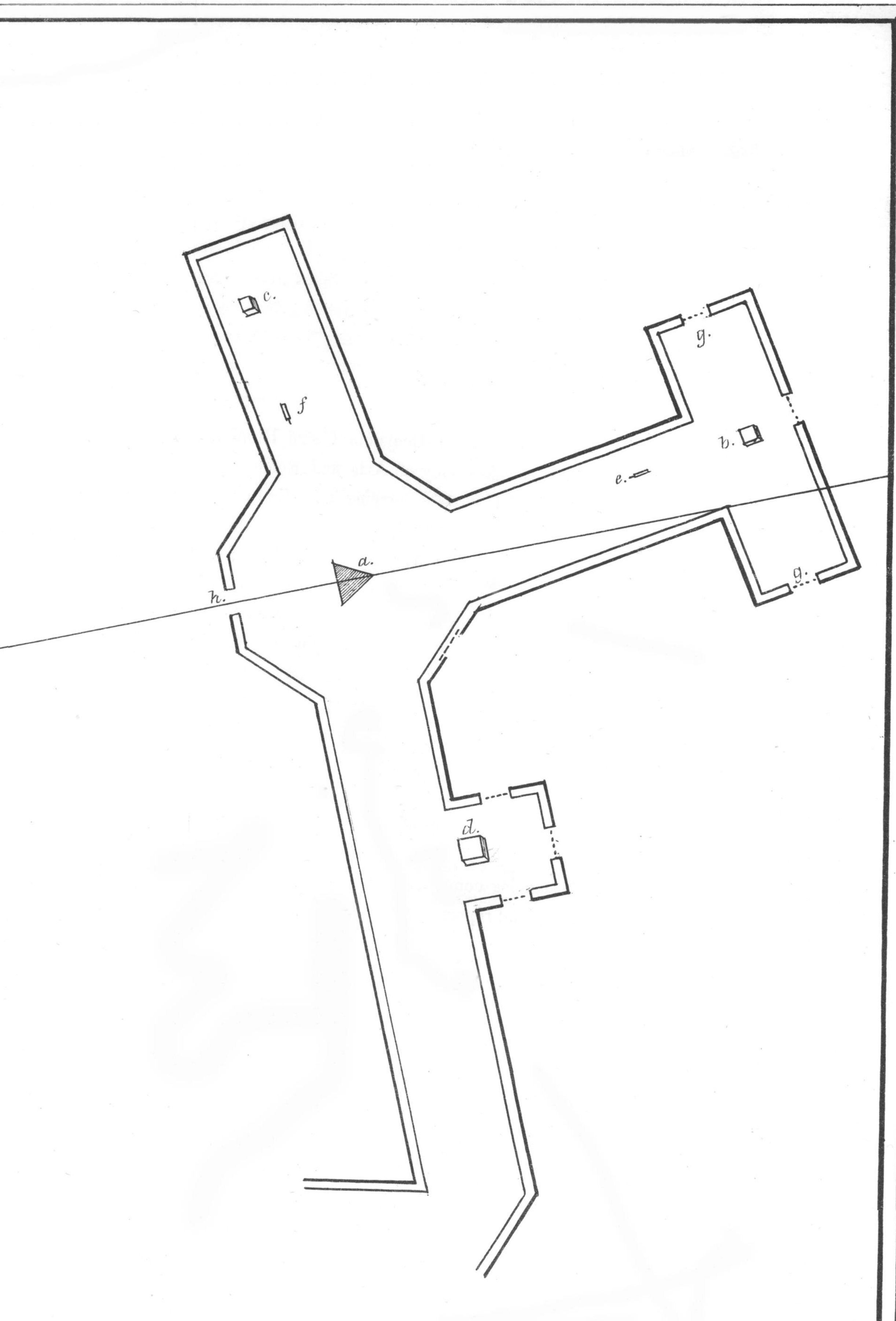
	June.			August.			September.			October.		
	Computed.	Observed.	Difference.	Computed.	Observed.	Difference.	Computed.	Observed.	Difference.	Computed.	Observed.	Difference.
I— 0	110.21	109.51	+ .70	125.92	126.22	— .30	101.90	99.74	+2.16	101.44	101.47	— .03
20	109.86	109.14	+ .72	125.56	125.18	+ .38	100.62	99.85	+ .77	101.50	101.41	+ .09
40	109.28	108.67	+ .61	125.06	124.95	+ .11	100.26	101.33	—1.07	101.46	101.69	— .23
II— 0	108.51	108.23	+ .28	124.44	124.42	+ .02	100.80	101.21	— .41	101.31	102.25	— .94
20	107.78	107.74	+ .04	123.71	123.79	— .08	100.29	100.16	+ .13	101.06	101.92	— .86
40	107.02	107.15	— .13	122.90	123.00	— .10	99.71	99.95	— .24	100.70	101.88	—1.18
III— 0	106.27	106.75	— .48	122.04	122.25	— .21	99.12	99.60	— .48	100.26	100.76	— .50
20	105.54	106.15	— .61	121.13	121.05	+ .08	98.54	98.47	+ .07	99.74	99.94	— .20
40	104.86	105.28	— .42	120.22	120.43	— .21	98.03	98.51	— .48	99.16	98.83	+ .33
IV— 0	104.34	104.28	+ .06	119.34	119.90	— .56	97.60	98.17	— .57	98.56	98.13	+ .43
20	103.69	103.69	.00	118.51	118.68	— .17	97.31	97.81	— .50	97.93	96.85	+1.08
40	103.19	103.07	+ .12	117.75	117.75	.00	97.19	96.94	+ .25	97.31	97.08	+ .23
V— 0	102.75	102.66	+ .09	117.09	117.20	— .11	97.20	96.52	+ .68	96.72	96.04	+ .68
20	102.35	102.25	+ .10	116.53	116.45	+ .08	97.41	97.81	— .40	96.17	95.93	+ .24
40	102.00	101.87	+ .13	116.09	116.03	+ .06	97.67	97.95	— .28	95.70	95.59	+ .11
VI— 0	101.60	101.64	— .04	115.78	115.85	— .07	98.28	98.06	+ .22	95.30	95.38	— .08
20	101.43	101.35	— .08	115.59	115.87	— .28	98.90	99.18	— .28	94.99	95.54	— .55
40	101.21	101.40	— .19	115.52	115.34	+ .18	99.60	100.17	— .57	94.79	95.58	— .79
VII— 0	101.04	100.98	+ .06	115.55	115.18	+ .37	100.31	100.63	— .32	94.68	95.22	— .54
20	100.93	100.87	+ .06	115.68	115.37	+ .31	101.03	100.00	+1.03	94.68	95.57	— .89
40	100.89	100.89	.00	115.88	115.69	+ .19	101.69	100.92	+ .77	94.74	95.53	— .79
VIII— 0	100.93	101.20	— .27	116.14	116.18	— .04	102.28	102.89	— .61	94.96	95.15	— .19
20	101.05	101.24	— .19	116.44	116.26	+ .18	102.78	102.26	+ .52	95.23	94.38	+ .85
40	101.26	101.34	— .08	116.76	116.35	+ .41	103.18	102.08	+1.10	95.57	94.84	+ .73
IX— 0	101.51	101.28	+ .23	117.09	116.84	+ .25	103.48	102.43	+1.05	95.97	94.96	+1.01
20	101.84	101.66	+ .18	117.41	117.47	— .06	103.69	101.63	+2.06	96.41	95.54	+ .87
40	102.19	102.30	— .11	117.72	118.18	— .46	103.84	102.38	+1.46	96.88	96.14	+ .74

This Table gives four monthly mean observed places of the Magnetometer for every 20 minutes during the day. A parallel column gives the corresponding place as calculated by the empirical curve. The column of differences shows to what extent the empirical and observed places agree, and the signs of these differences make it probable that they are accidental. The numbers in all these Tables are in minutes and decimal parts of a minute, according to the scale of the Gauss Magnetometer



C.
D
F
I.
B.
H.
F.
F.
G
E.
K.


J.
117.5 Feet from B.to a.
m.
n.
o.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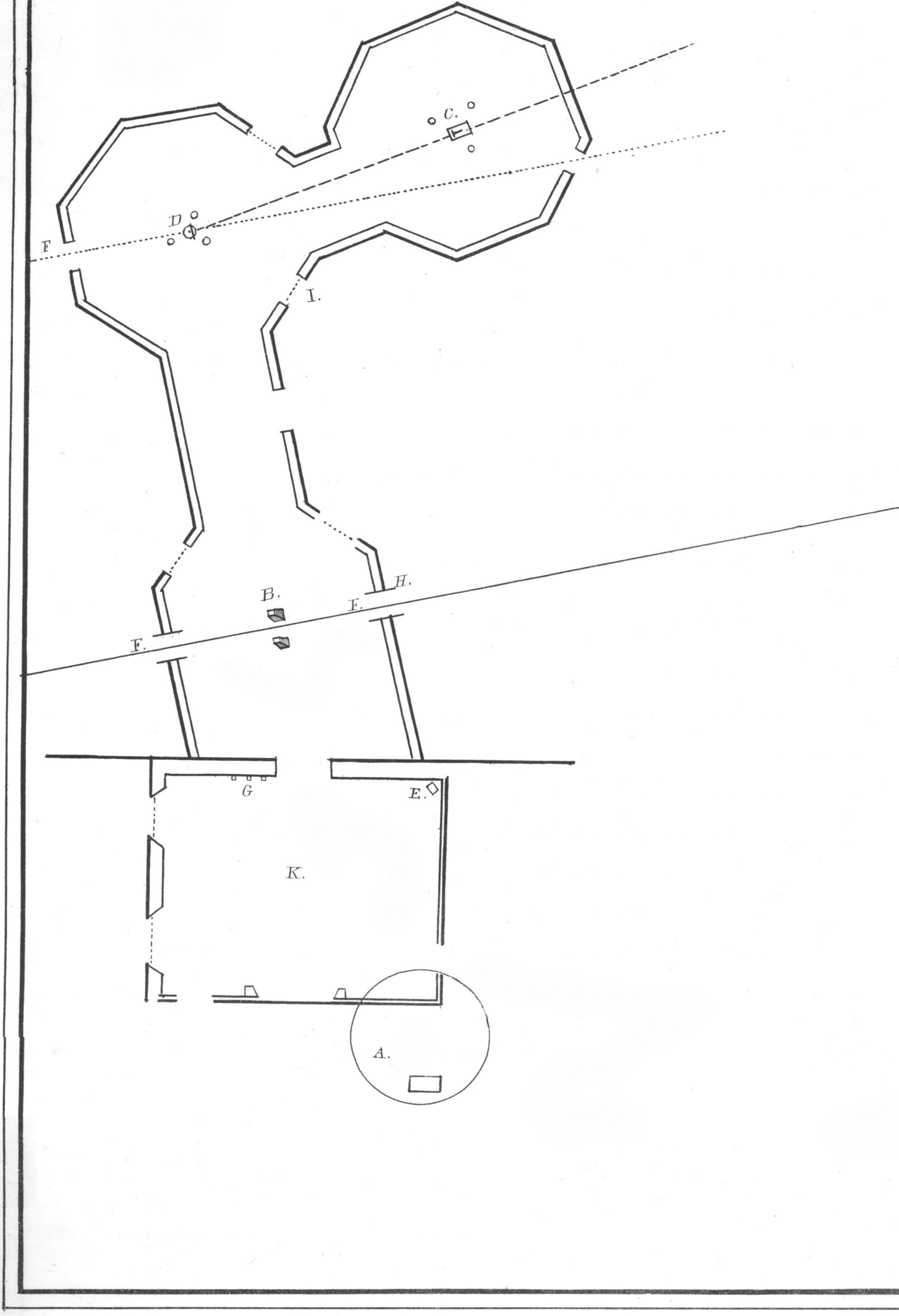
C.
D
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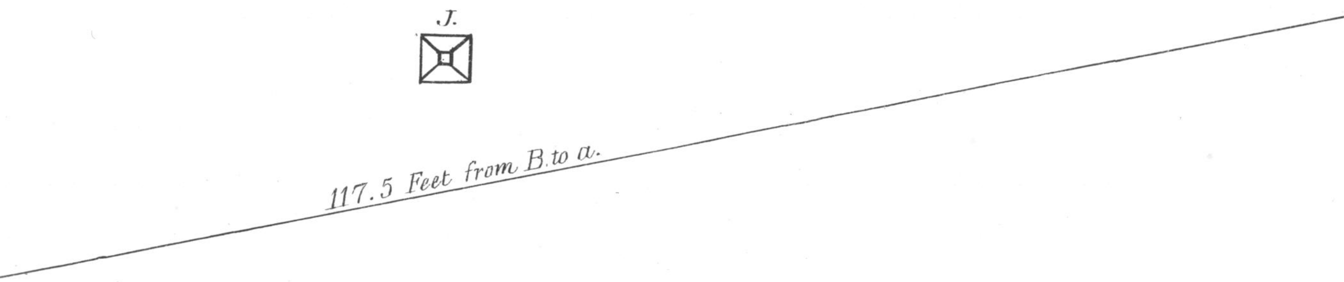
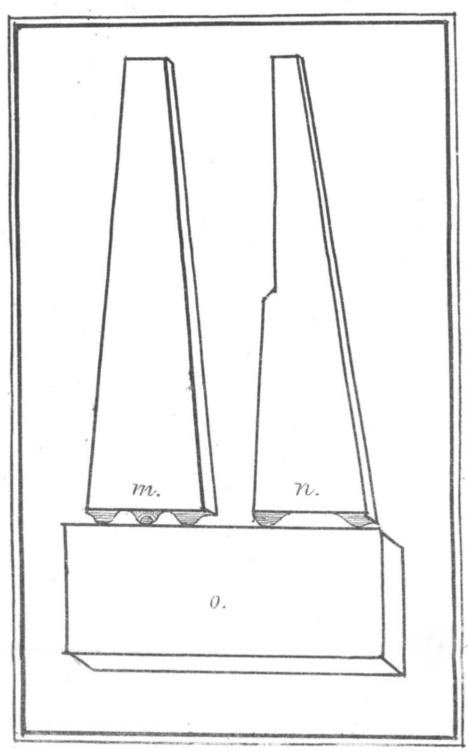
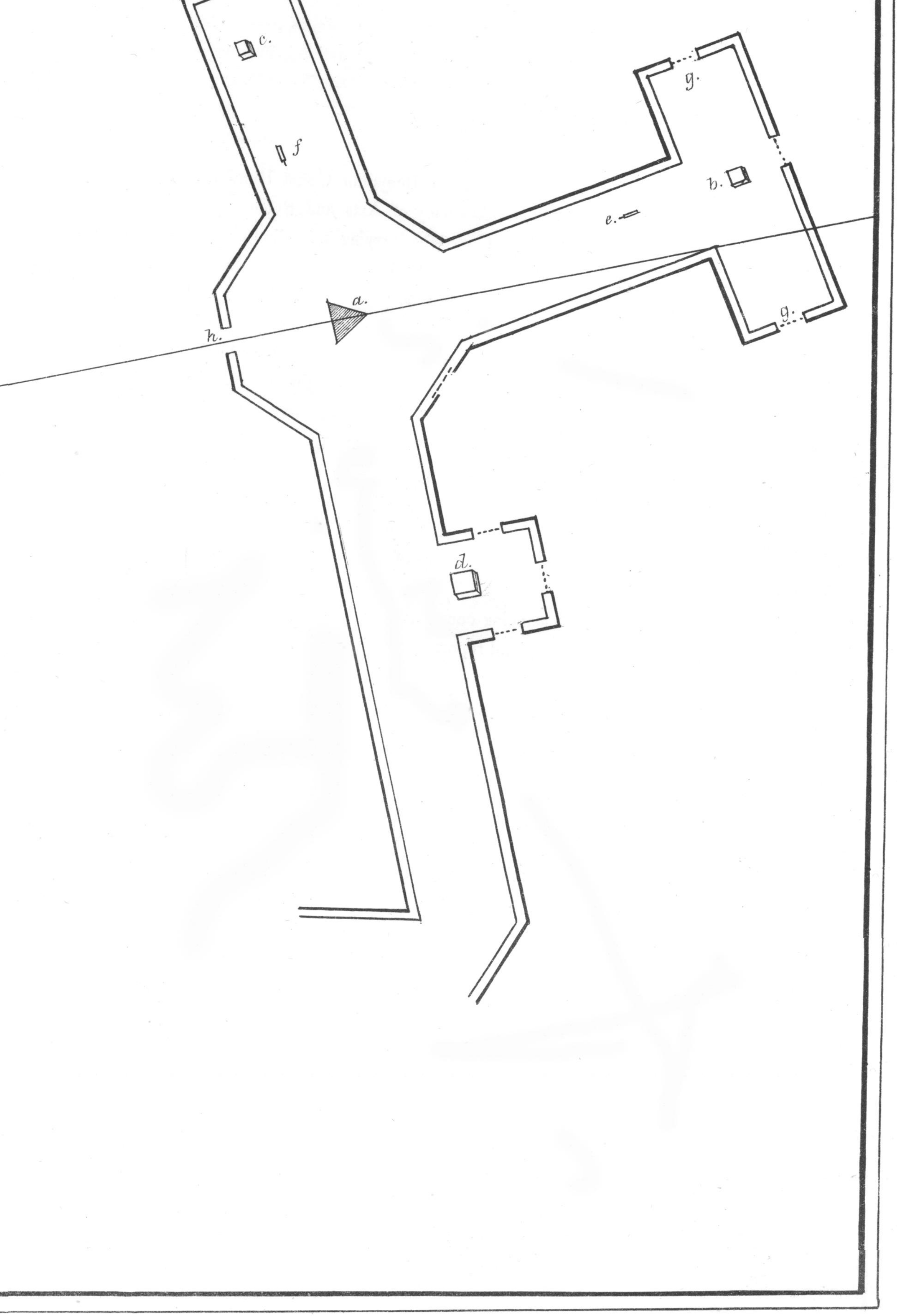
A.





Thayer's Lith Boston


c.
g.
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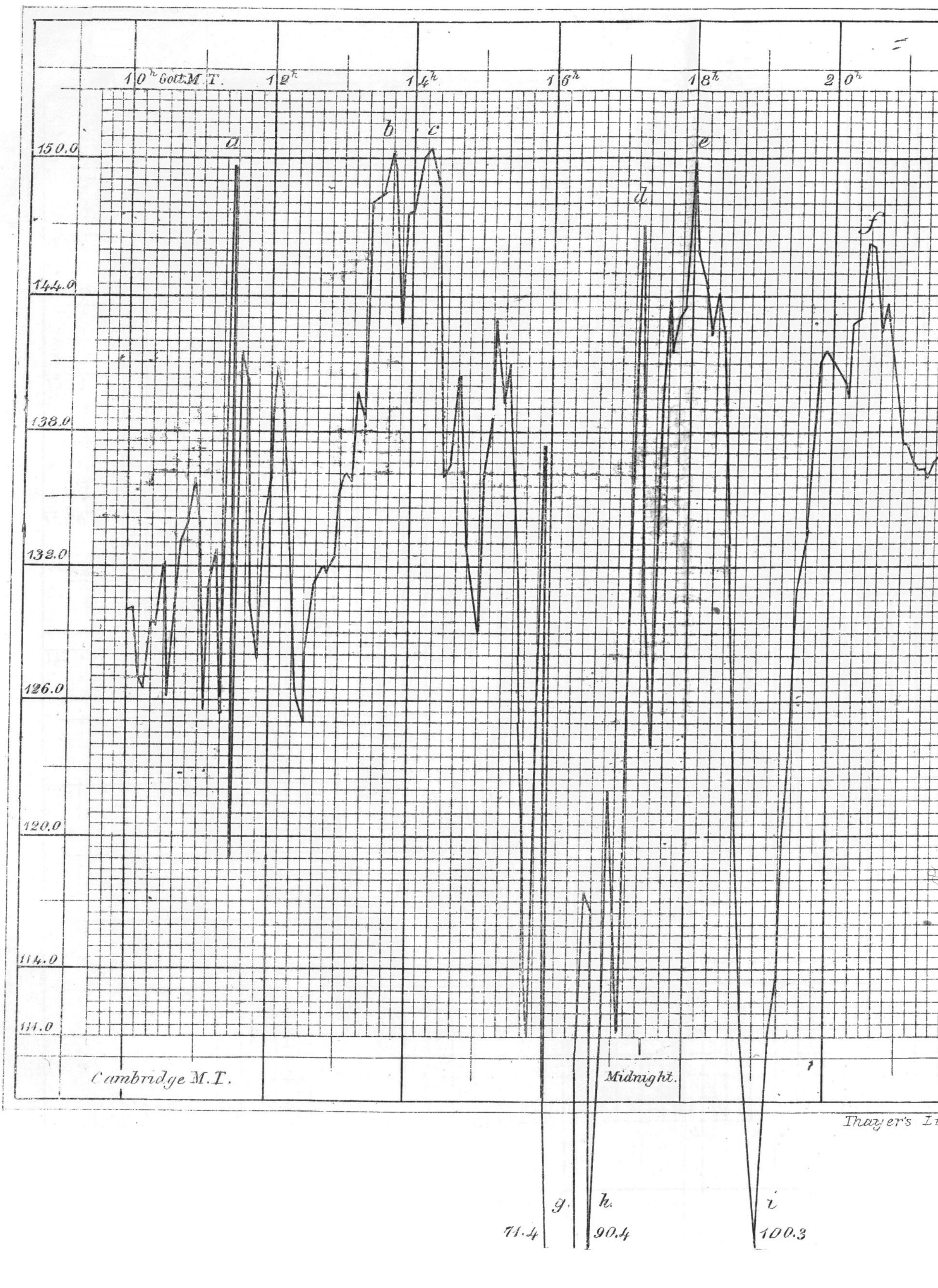
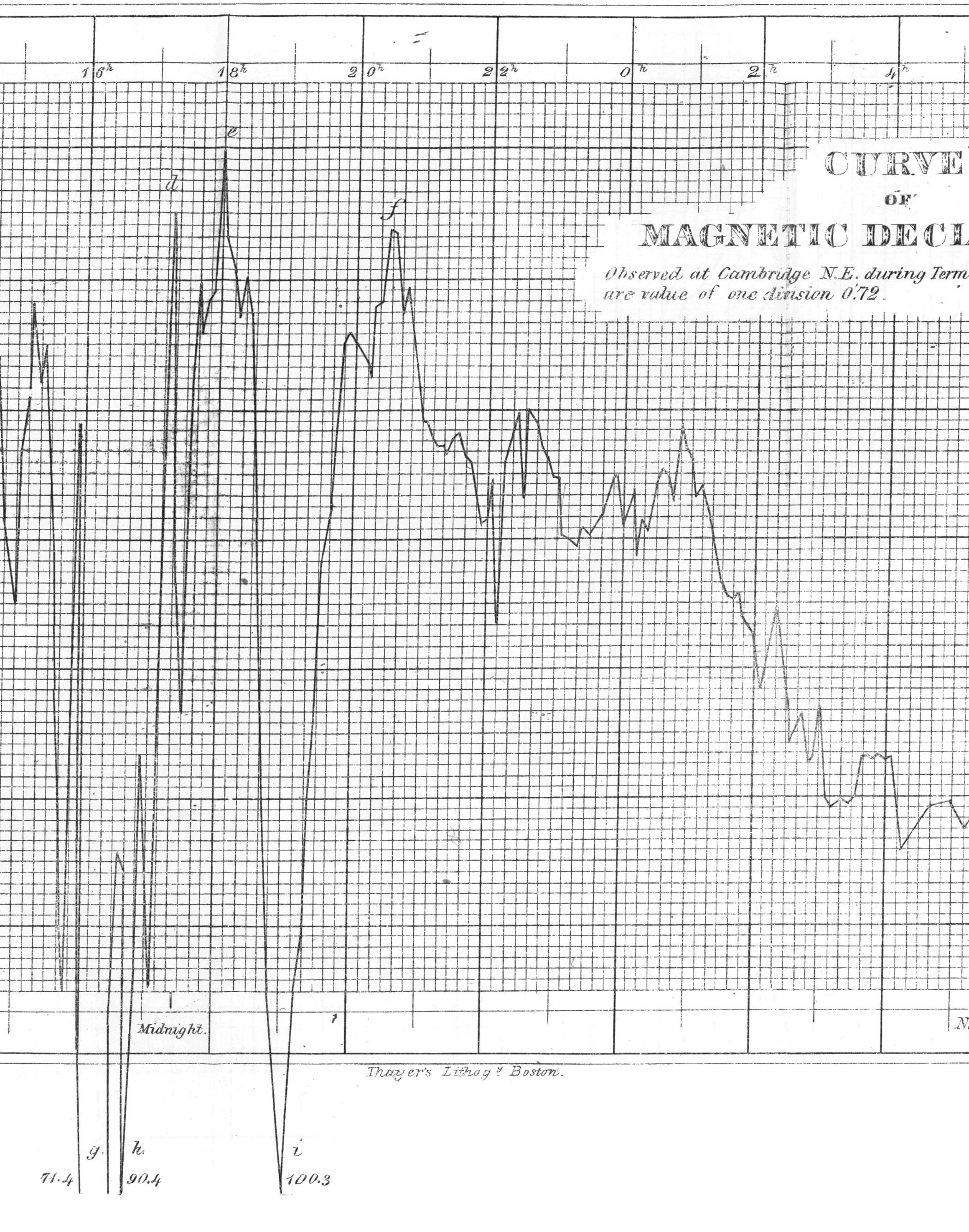
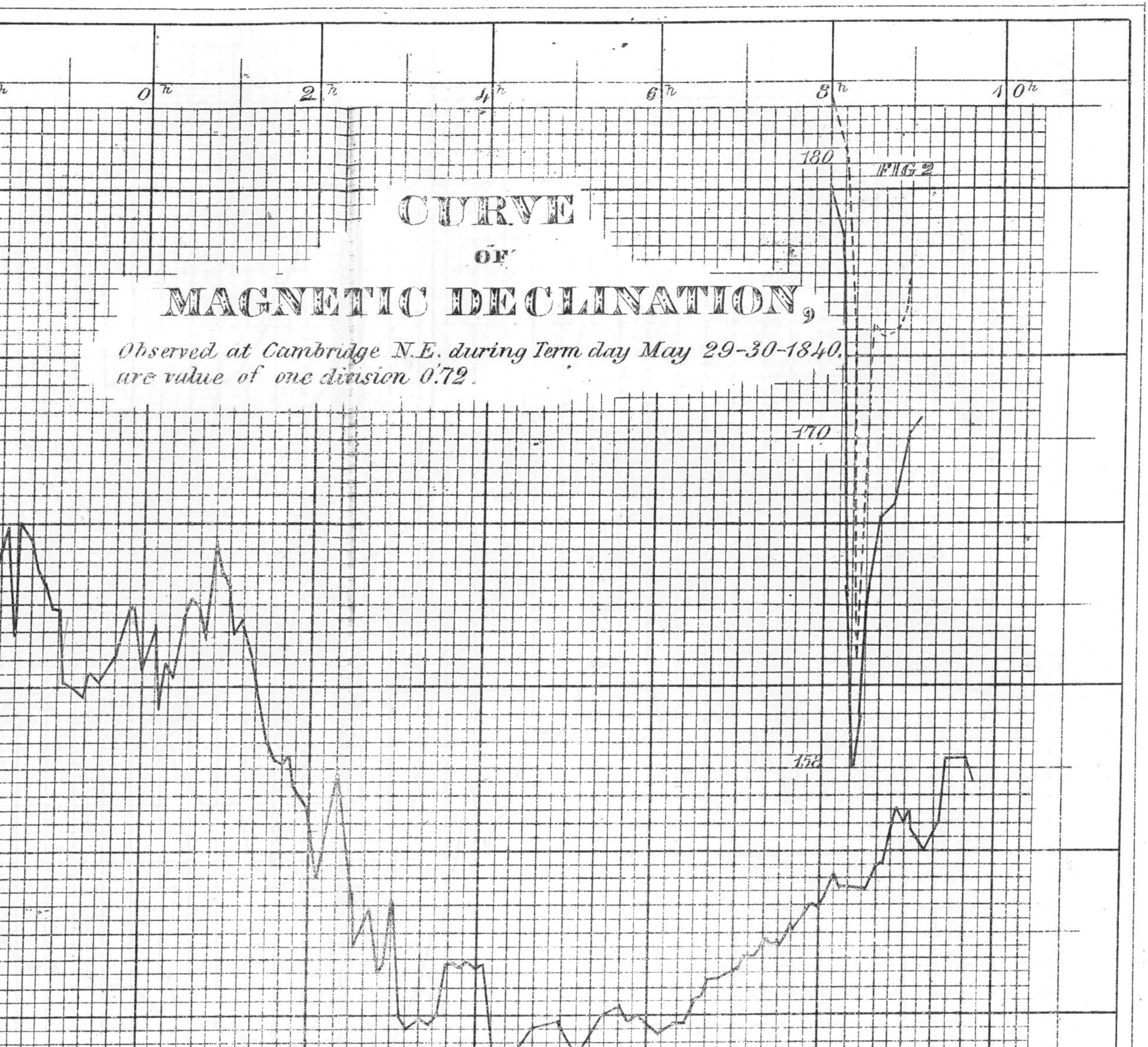


10h Gött.M.T.
12h
14h
16h
18h
20h
150.0
144.0
138.0
132.0
126.0
120.0
114.0
111.0
a
b
c
d
e
f
g
h
i
71.4
90.4
100.3
Cambridge M.T.
Midnight.

Thayer's L

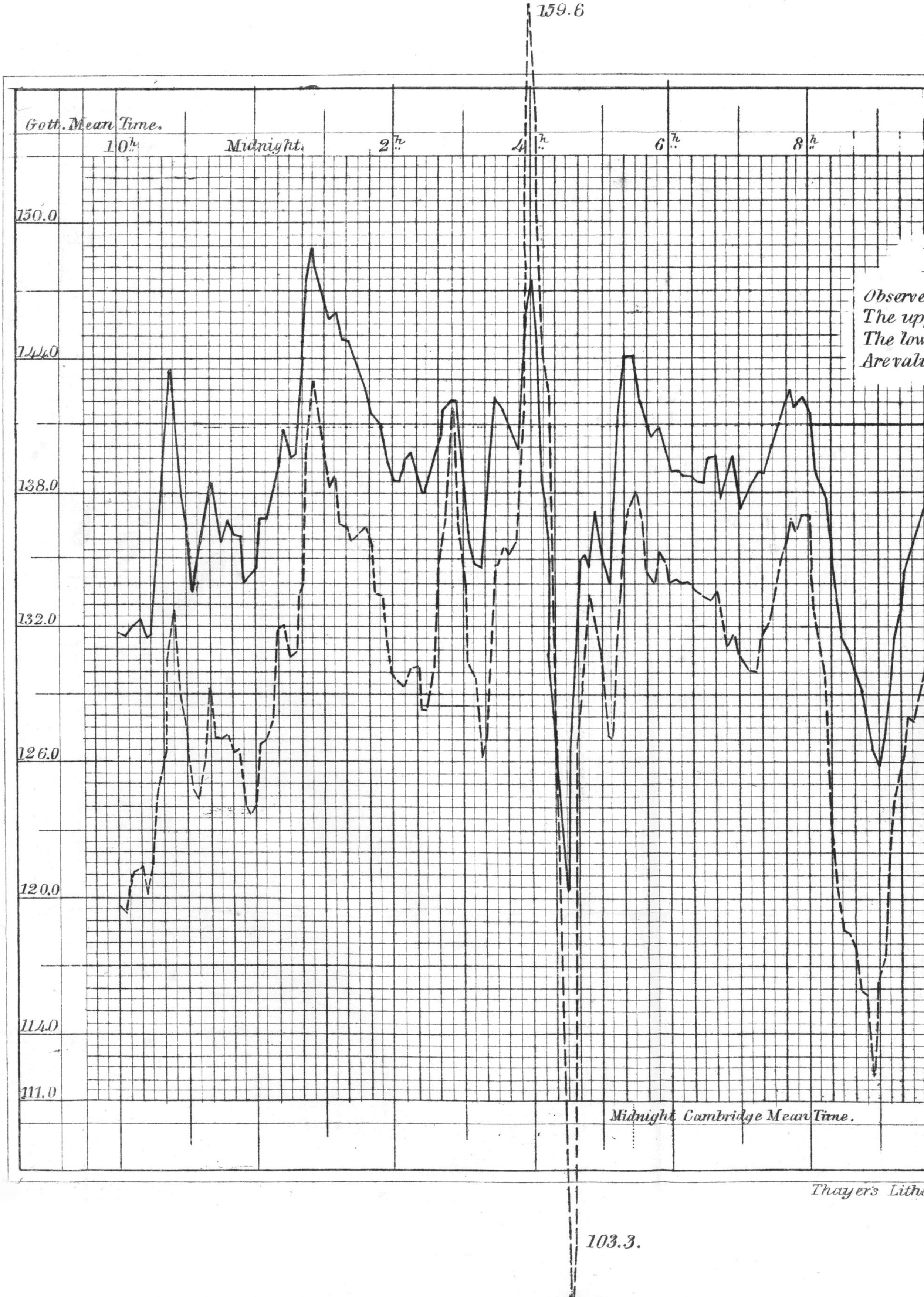


Thayer's Lithog.y Boston.

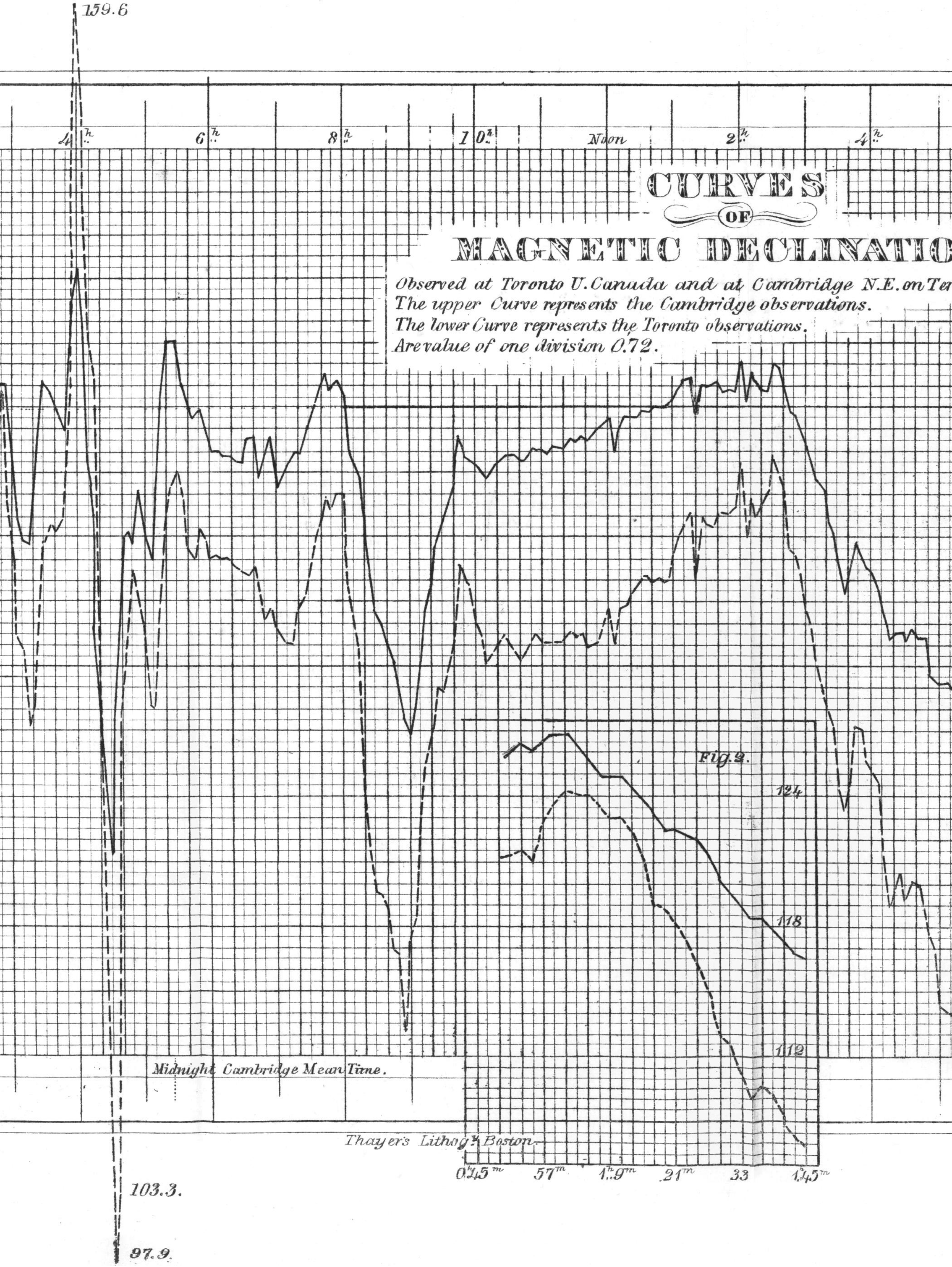


CURVE OF MAGNETIC DECLINATION,
Observed at Cambridge N.E. during Term day May 29-30-1840,
arc value of one division 0'.72.
0h
2h
4h
6h
8h
10h
180
FIG 2
170
158
Noon.

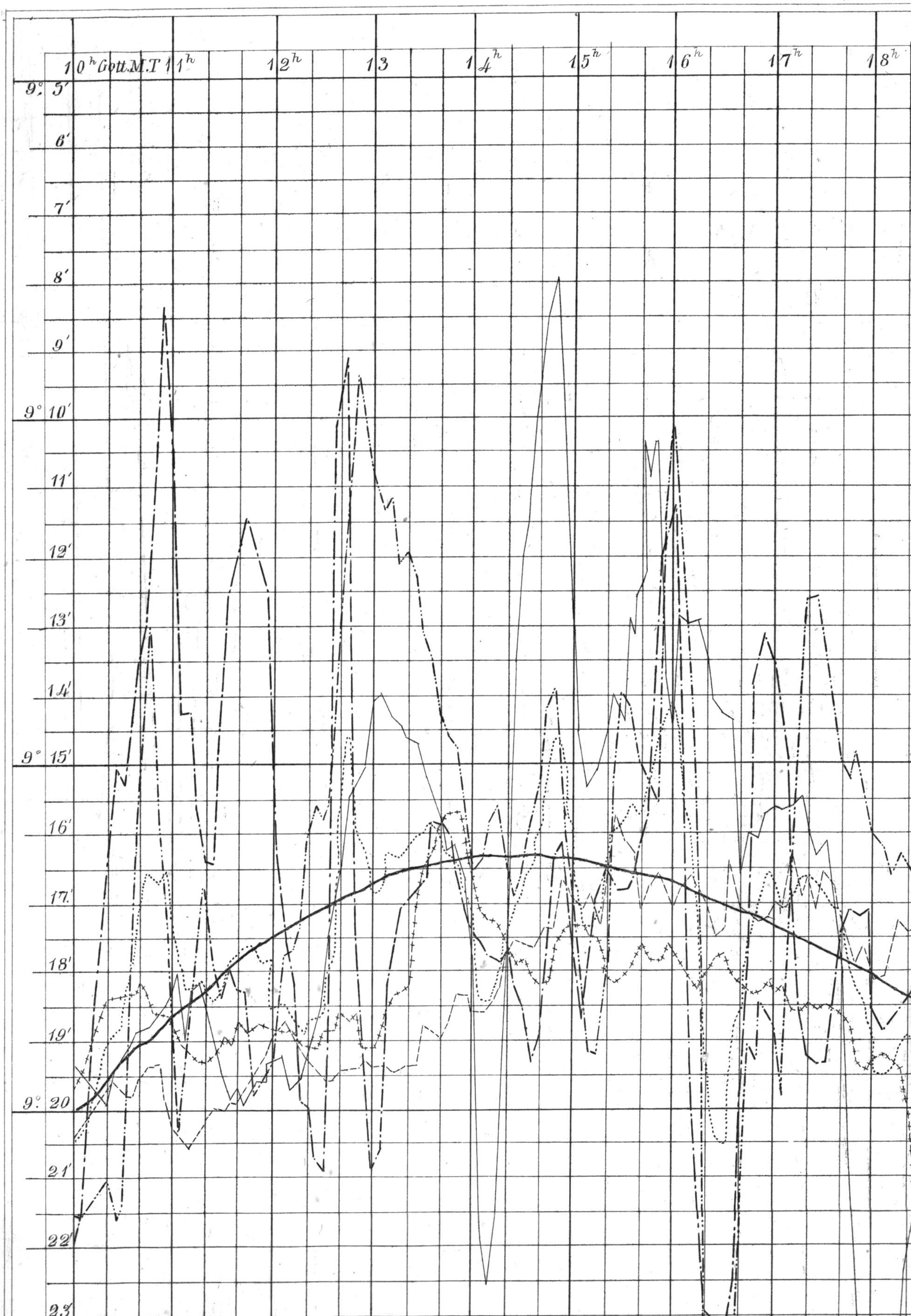
Boston.



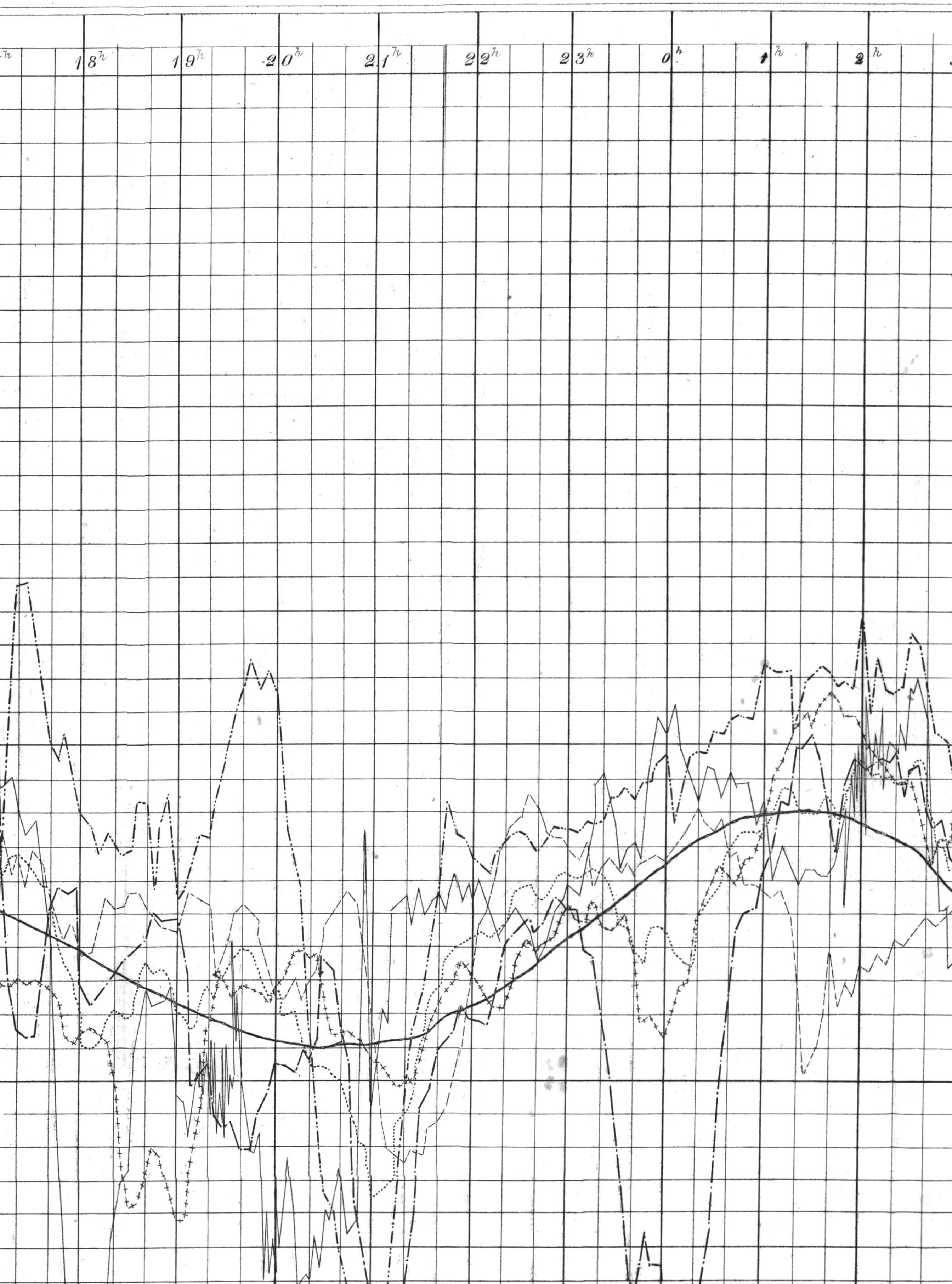
Thayer's Litho


159.6
4h
6h
8h
10h
Noon
2h
4h
CURVES
OF
MAGNETIC DECLINATIO
Observed at Toronto U. Canada and at Cambridge N.E. on Ter
The upper Curve represents the Cambridge observations.
The lower Curve represents the Toronto observations.
Arc value of one division 0.72.
Fig. 2.
124
118
112
Midnight Cambridge Mean Time.
Thayer's Lithog. Boston.
0h45m
57m
1h9m
21m
33
1h45m
103.3.
97.9.

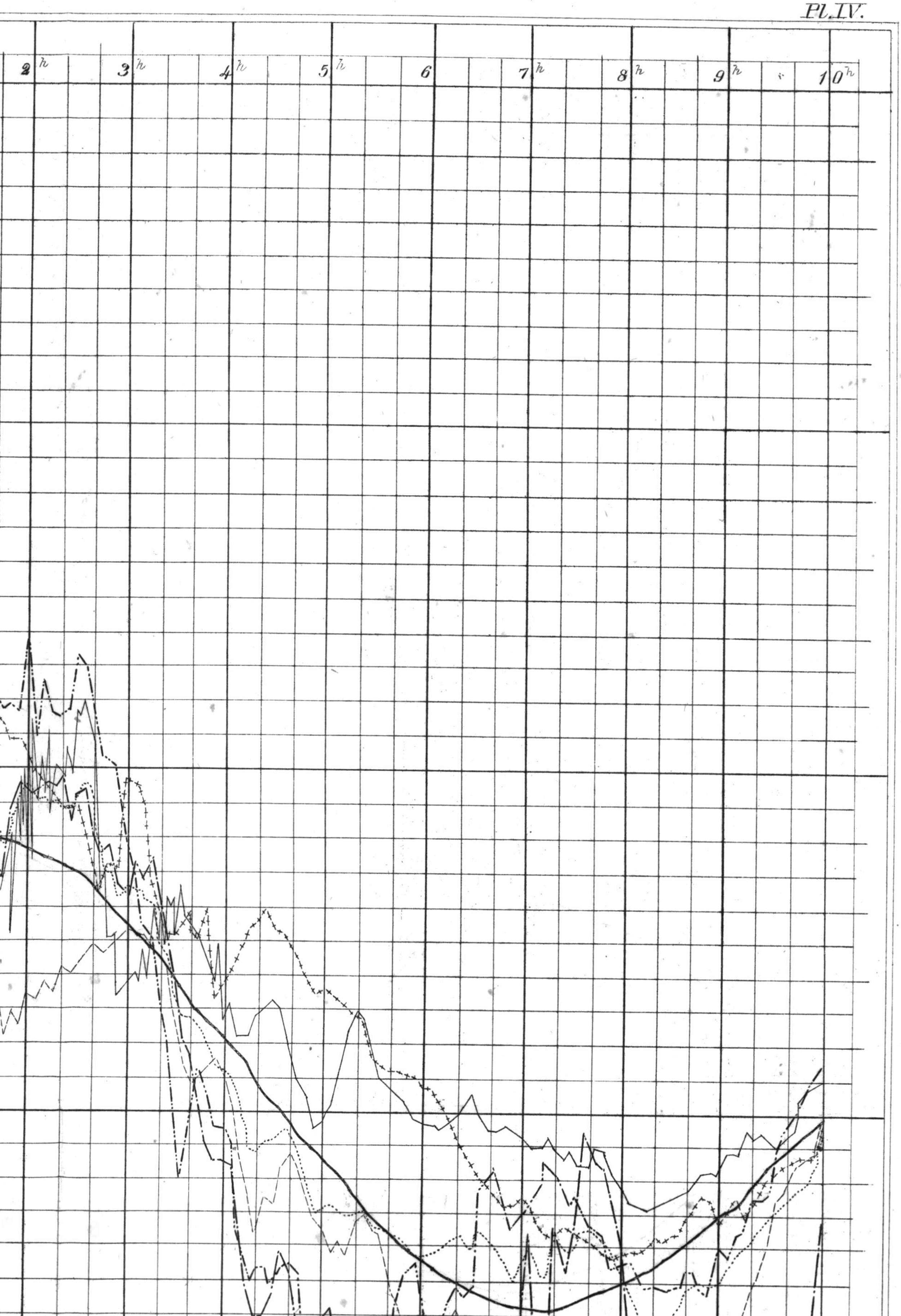

Noon
2h
4h
6h
8h
10h
CURVES
OF
AGNETIC DECLINATION,
Toronto U. Canada and at Cambridge N.E. on Term day Oct. 21st 1840,
Curve represents the Cambridge observations.
rve represents the Toronto observations.
one division 0.72.
Fig. 2.
124
118
112
noon.
oston.
57m
1h 9m
21m
33
1h 45m

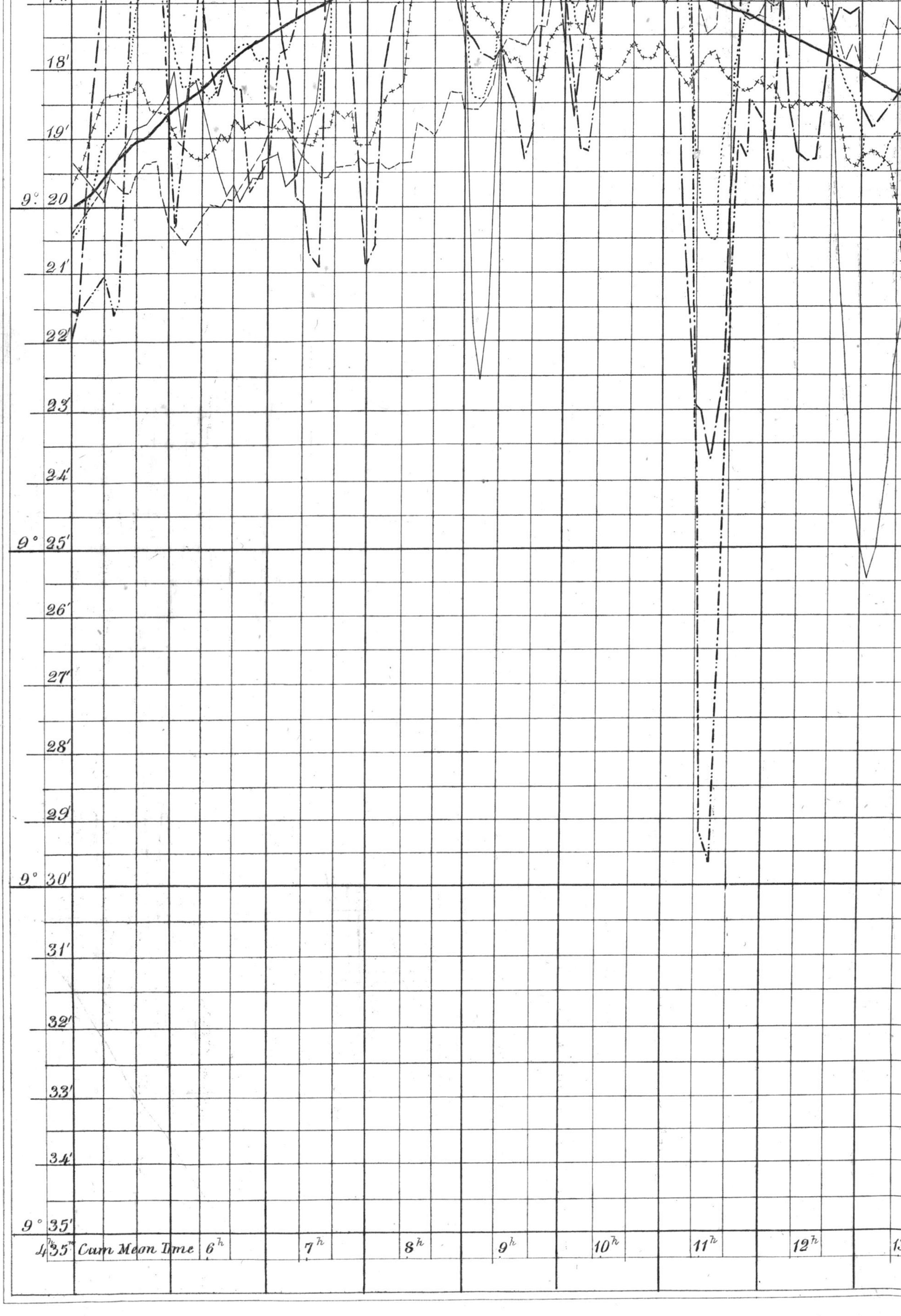


10h Gött.M.T.
11h
12h
13
14h
15h
16h
17h
18h
9° 5′
6′
7′
8′
9′
9° 10′
11′
12′
13′
14′
9° 15′
16′
17′
18′
19′
9° 20
21′
22′
23′

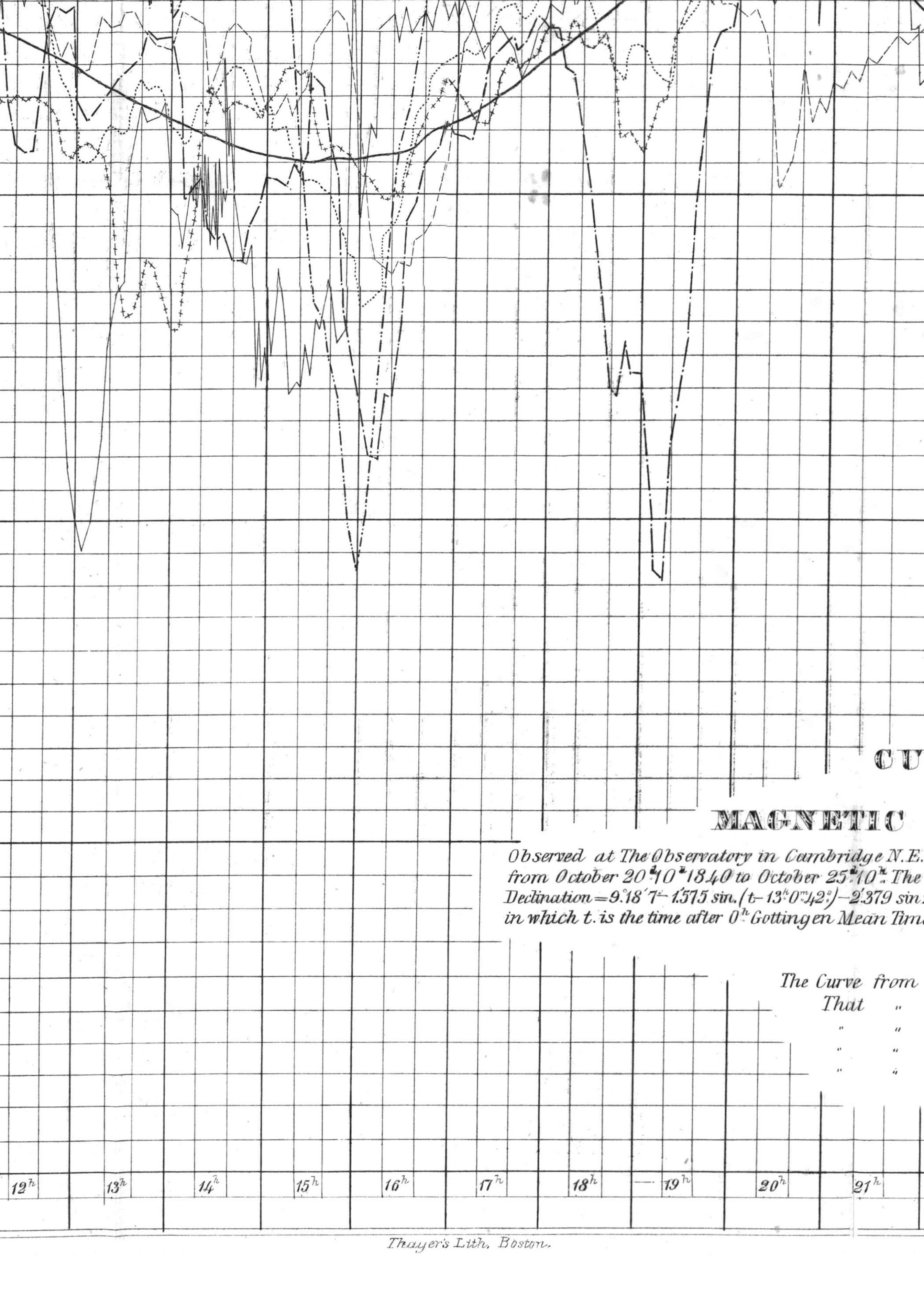

18h
19h
20h
21h
22h
23h
0h
1h
2h

Pl. IV.

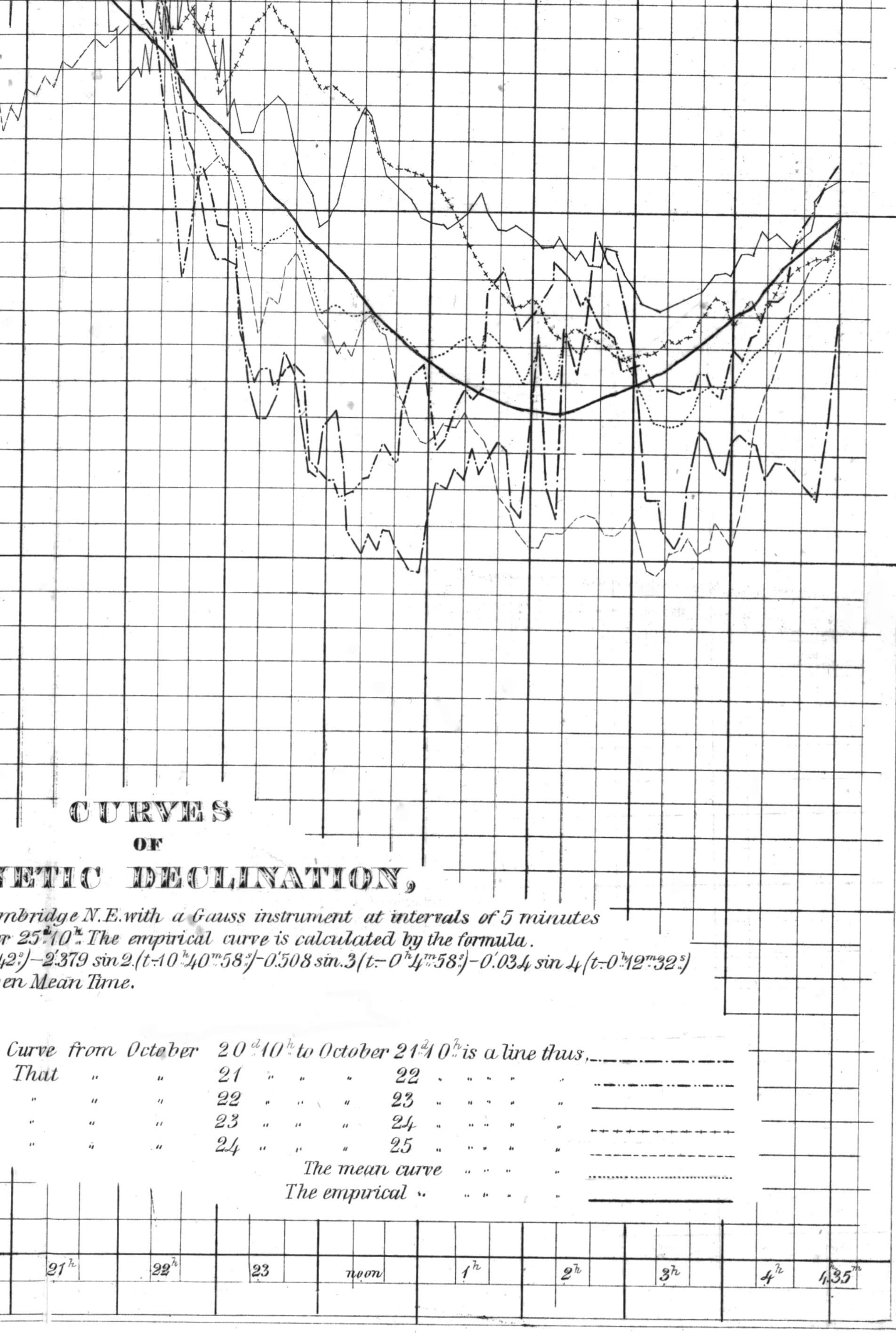


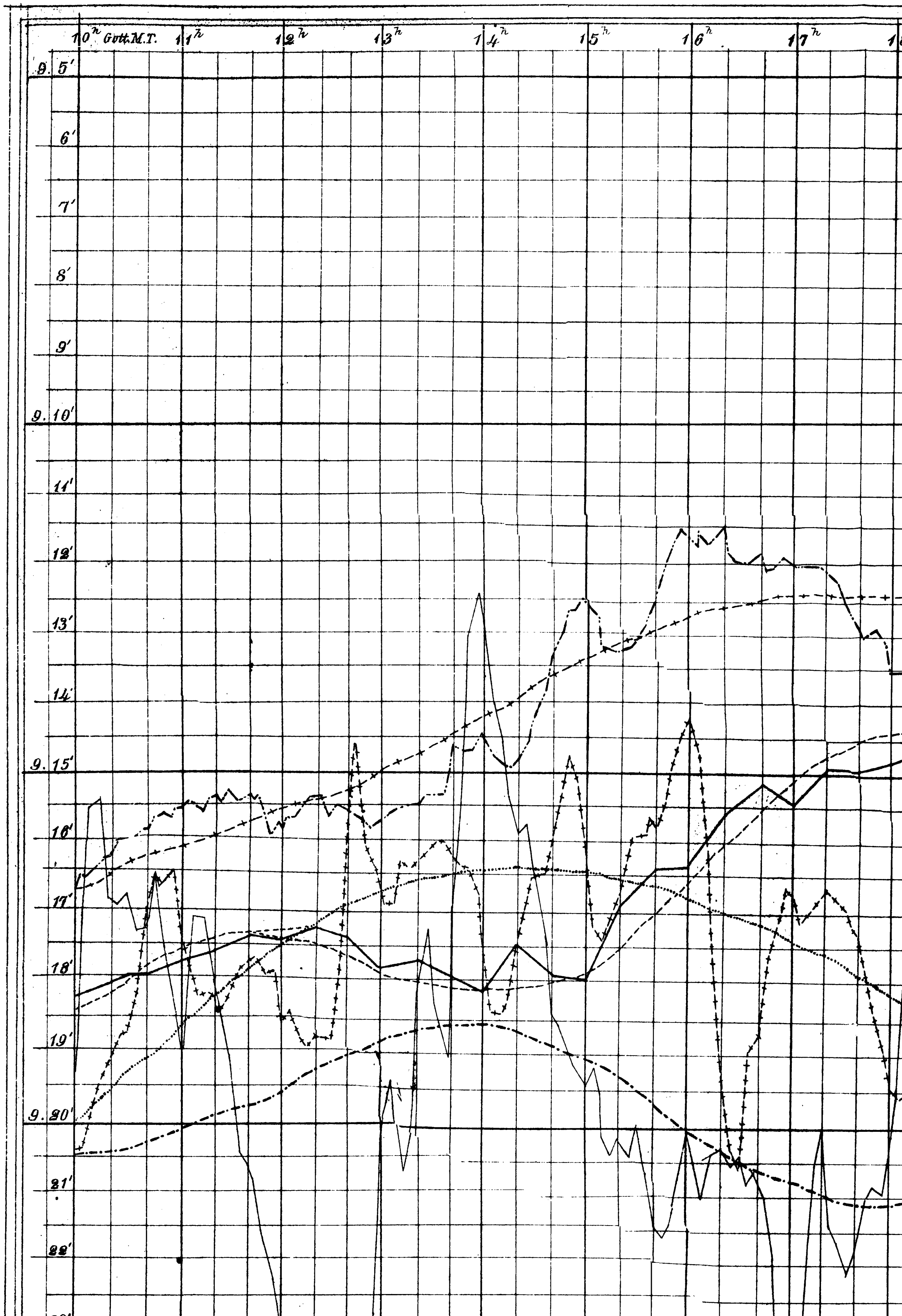


18'
19'
9° 20
21'
22'
23'
24'
9° 25'
26'
27'
28'
29'
9° 30'
31'
32'
33'
34'
9° 35'
4h 35m Cam Mean Time
6h
7h
8h
9h
10h
11h
12h

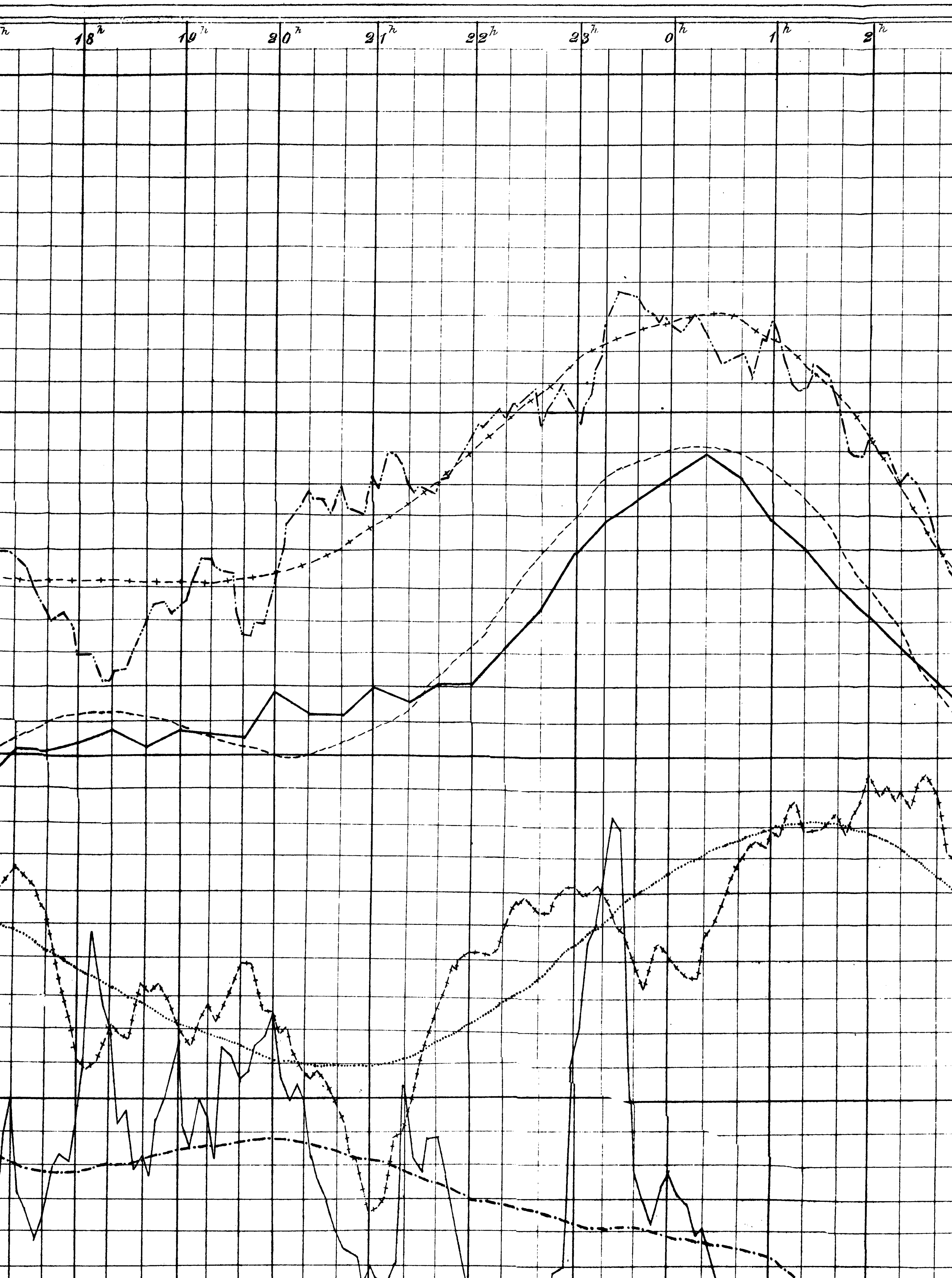


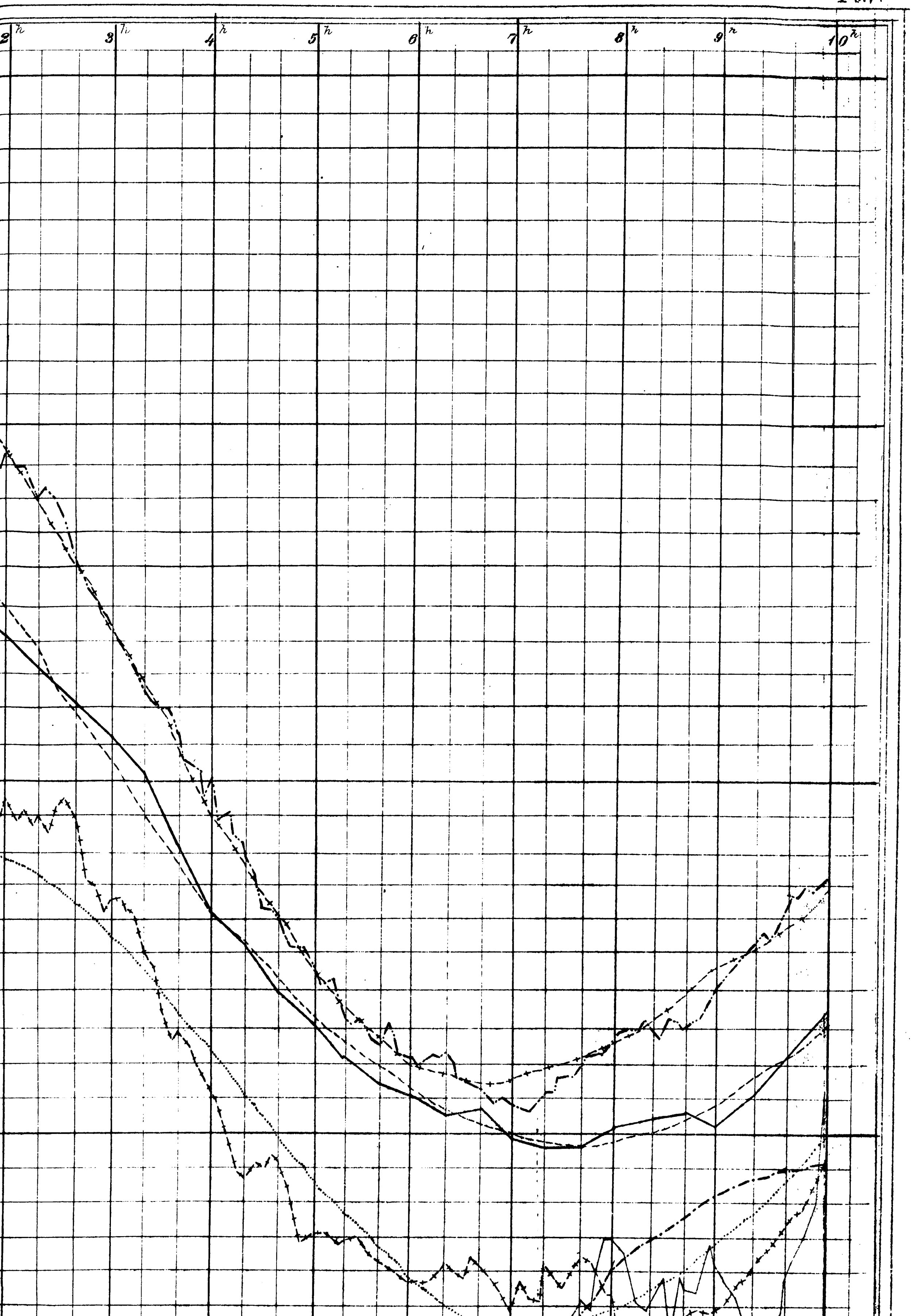
Thayer's Lith. Boston.


CURVES
OF
NETIC DECLINATION,
nbridge N.E. with a Gauss instrument at intervals of 5 minutes
r 25d 10h. The empirical curve is calculated by the formula.
42s)−2'.379 sin 2.(t−10h 40m 58s)−0'.508 sin. 3(t−0h 4m 58s)−0'.034 sin 4(t−0h 12m 32s)
en Mean Time.
Curve from October 20d 10h to October 21d 10h is a line thus,
That " " 21 " " " 22 " " " " "
" " " 22 " " " 23 " " " " "
" " " 23 " " " 24 " " " " "
" " " 24 " " " 25 " " " " "
The mean curve " " " "
The empirical " " " " "
21h
22h
23
noon
1h
2h
3h
4h
4h 35m

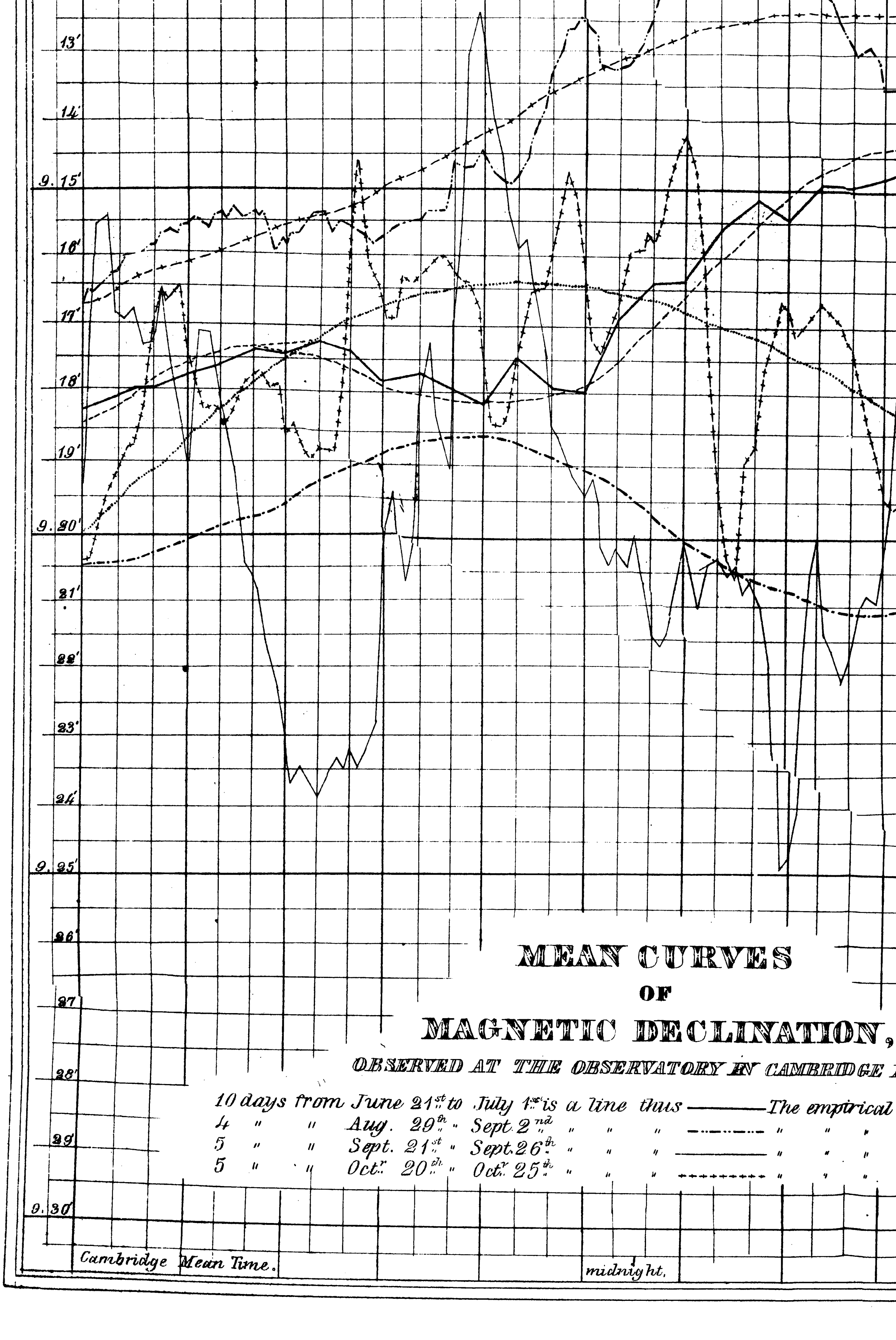


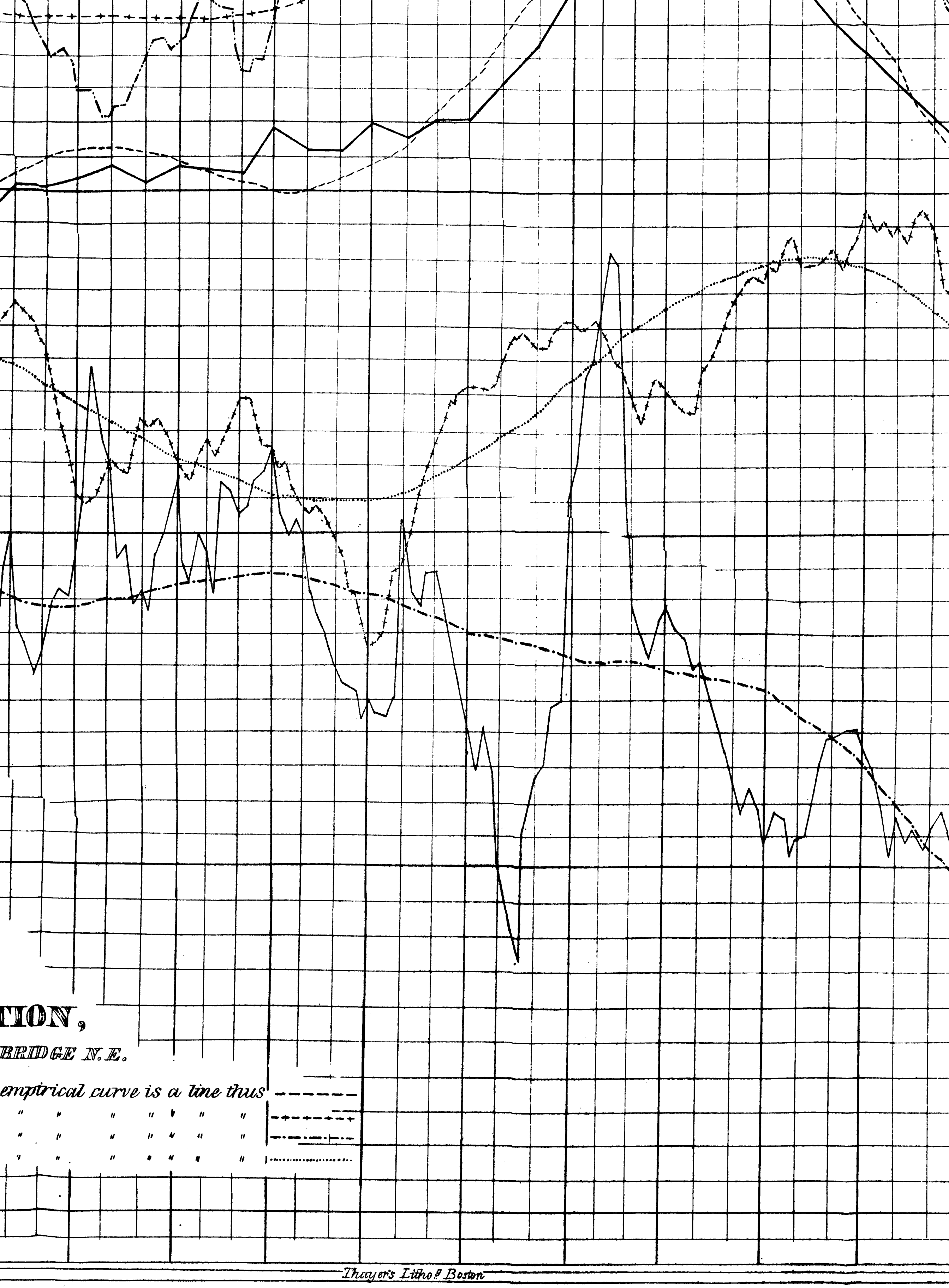
10h Gott.M.T.
11h
12h
13h
14h
15h
16h
17h
9. 5'
6'
7'
8'
9'
9. 10'
11'
12'
13'
14'
9. 15'
16'
17'
18'
19'
9. 20'
21'
22'

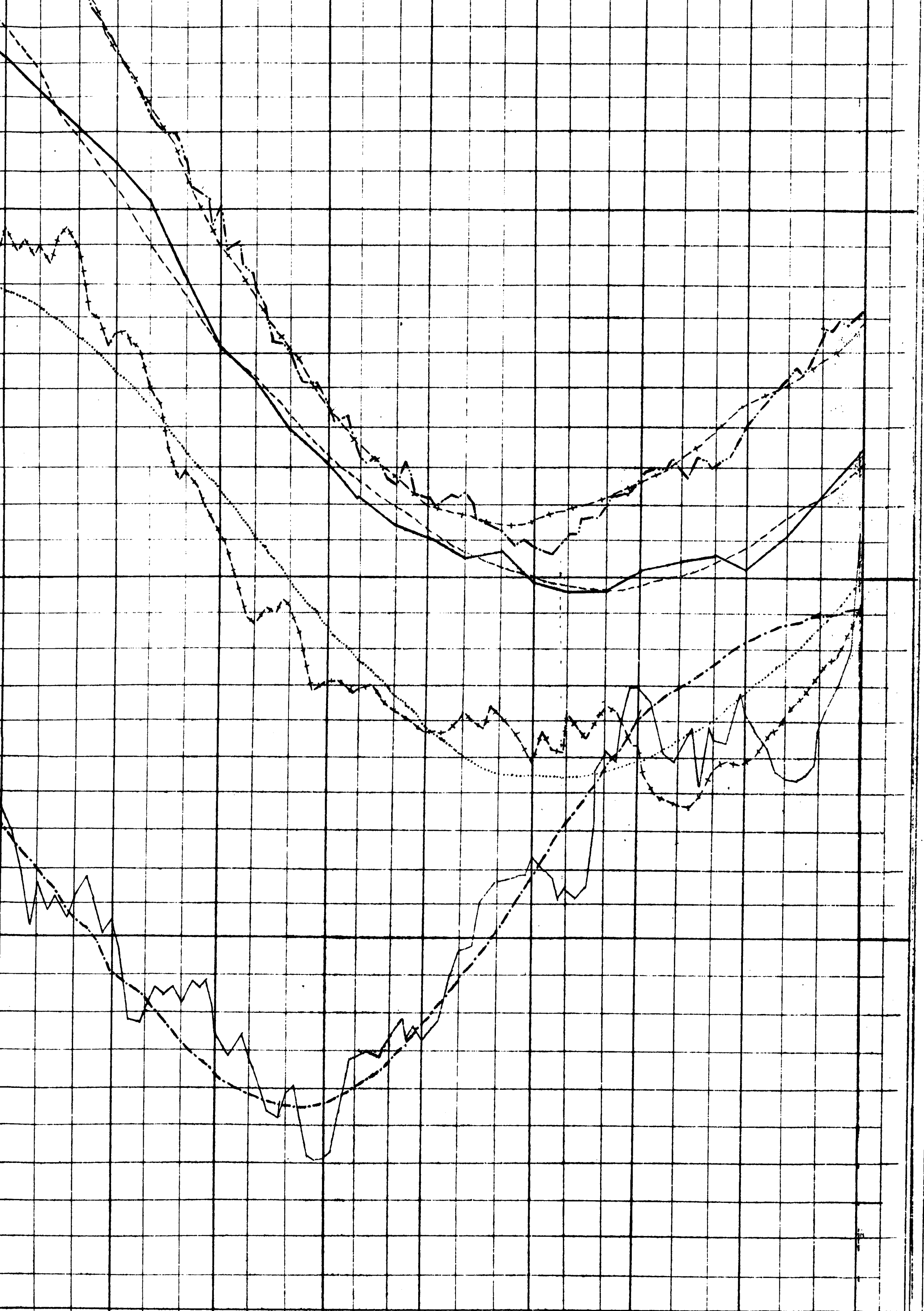

18h
19h
20h
21h
22h
23h
0h
1h
2h

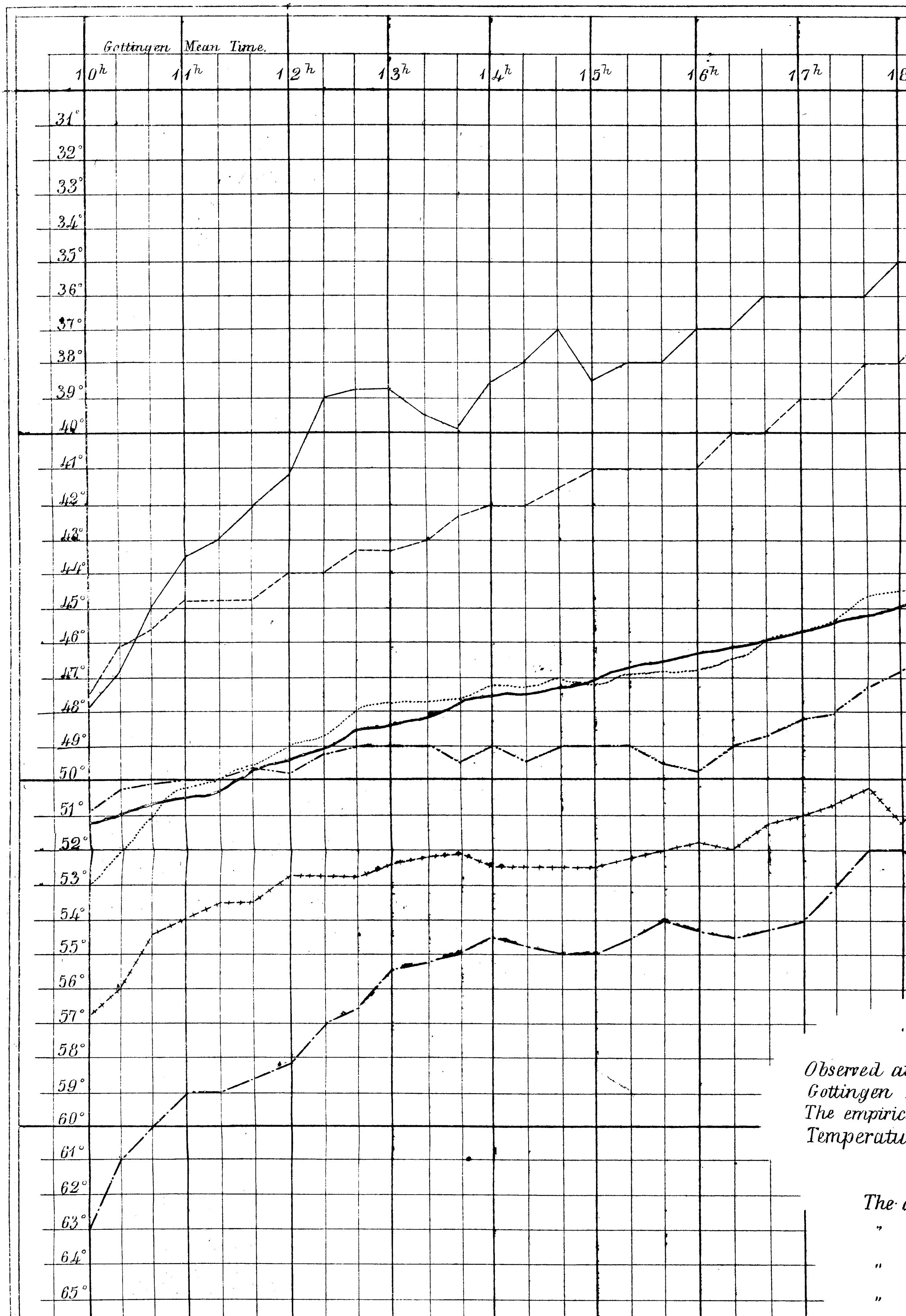


2h
3h
4h
5h
6h
7h
8h
9h
10h

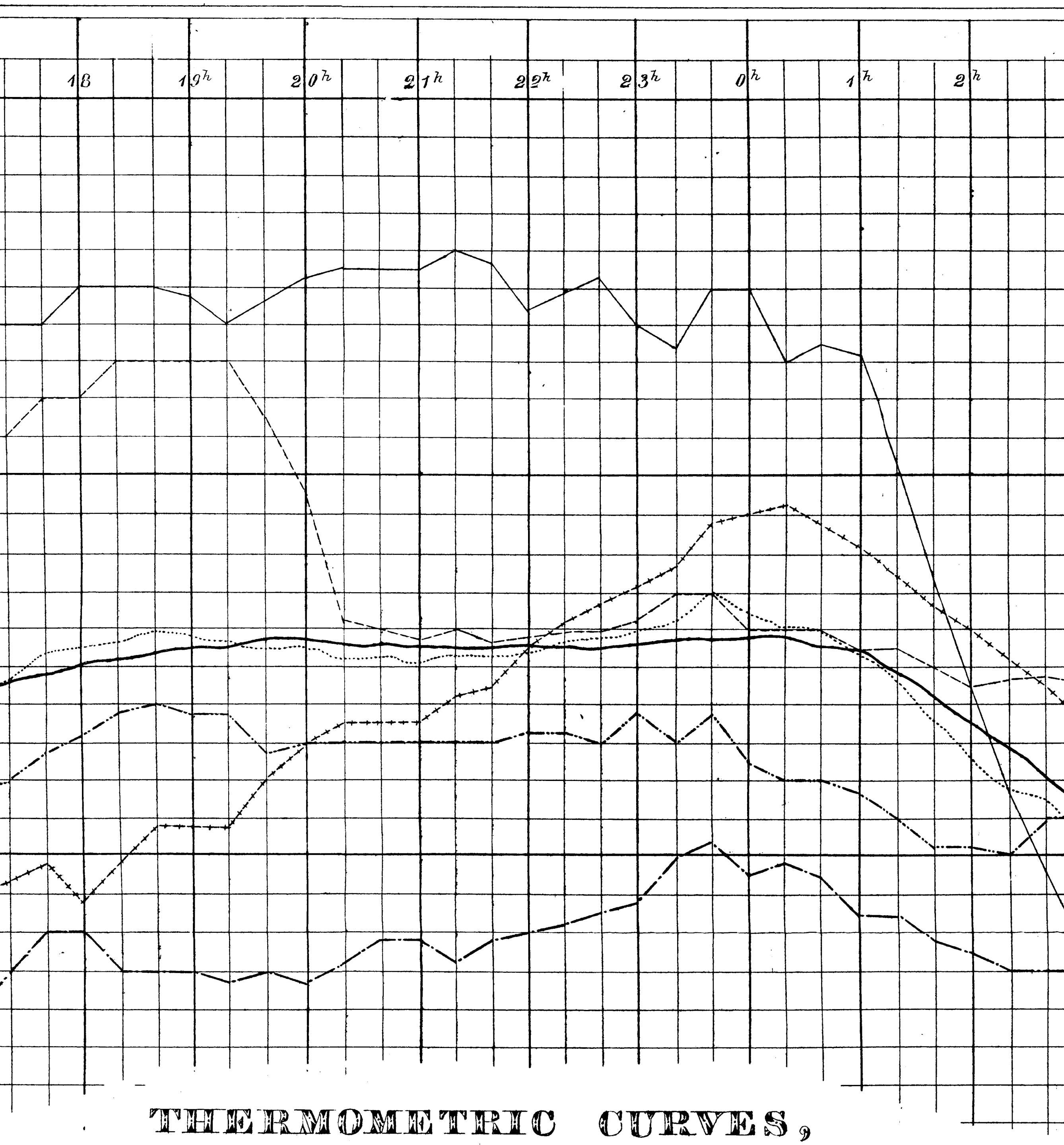

13'
14'
9.15'
16'
17'
18'
19'
9.20'
21'
22'
23'
24'
9.25'
26'
27'
28'
29'
9.30'
MEAN CURVES
OF
MAGNETIC DECLINATION,
OBSERVED AT THE OBSERVATORY IN CAMBRIDGE
10 days from June 21st to July 1st is a line thus ——— The empirical
4 " " Aug. 29th " Sept 2nd " " "
5 " " Sept. 21st " Sept. 26th " " "
5 " " Octr. 20th " Octr. 25th " " "
Cambridge Mean Time.
midnight.

TION,
BRIDGE N.E.
empirical curve is a line thus
Thayer's Litho. Boston


noon



Gottingen Mean Time.
10h
11h
12h
13h
14h
15h
16h
17h
31°
32°
33°
34°
35°
36°
37°
38°
39°
40°
41°
42°
43°
44°
45°
46°
47°
48°
49°
50°
51°
52°
53°
54°
55°
56°
57°
58°
59°
60°
61°
62°
63°
64°
65°



THERMOMETRIC CURVES,

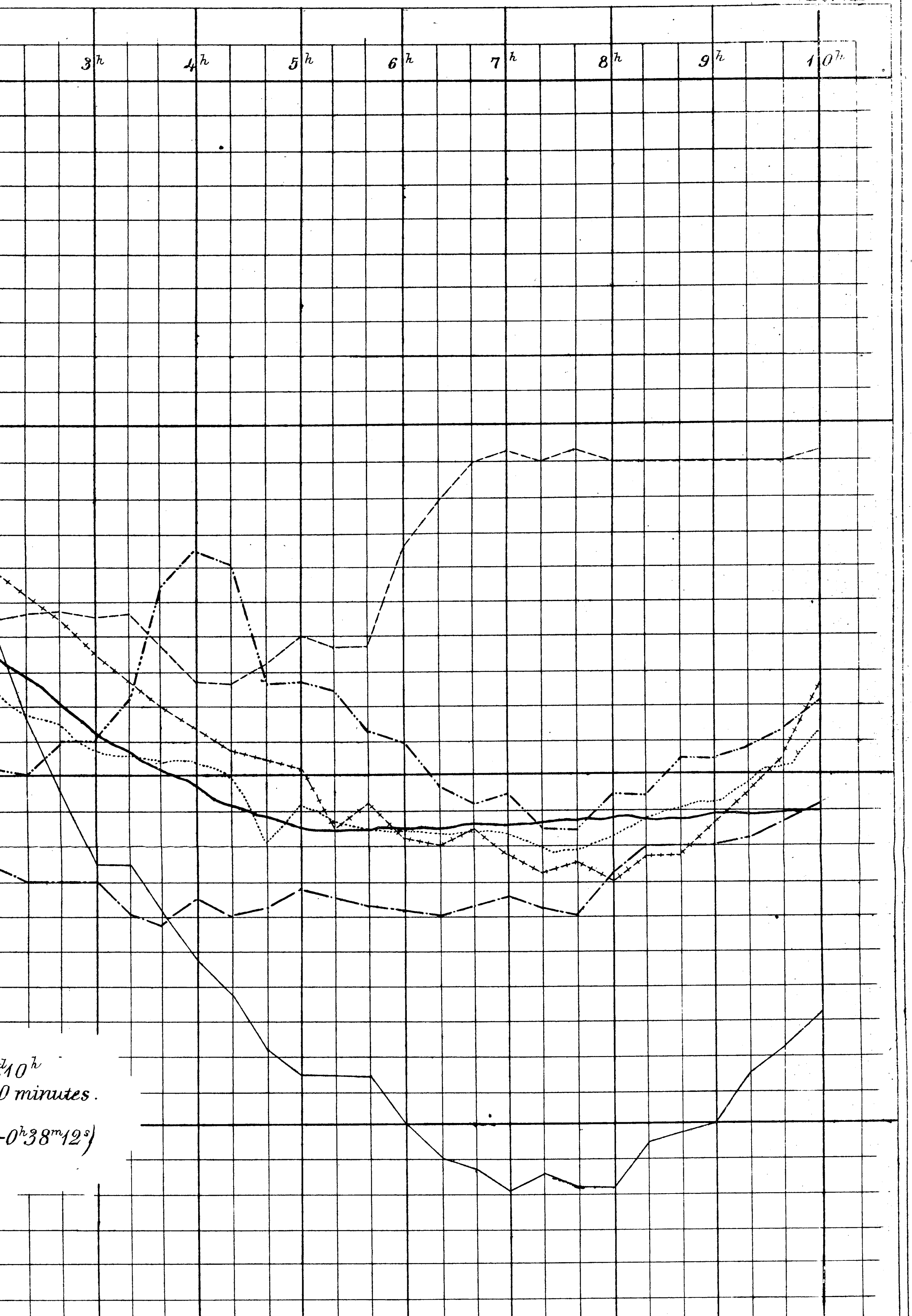
…served at the Observatory in Cambridge N.E. during the five days commencing 1840 October $20^d 10^h$ …ttingen Mean Time, and ending October $25^d 10^h$. The observations were made at intervals of 20 minute…
…e empirical curve is calculated by the formula.

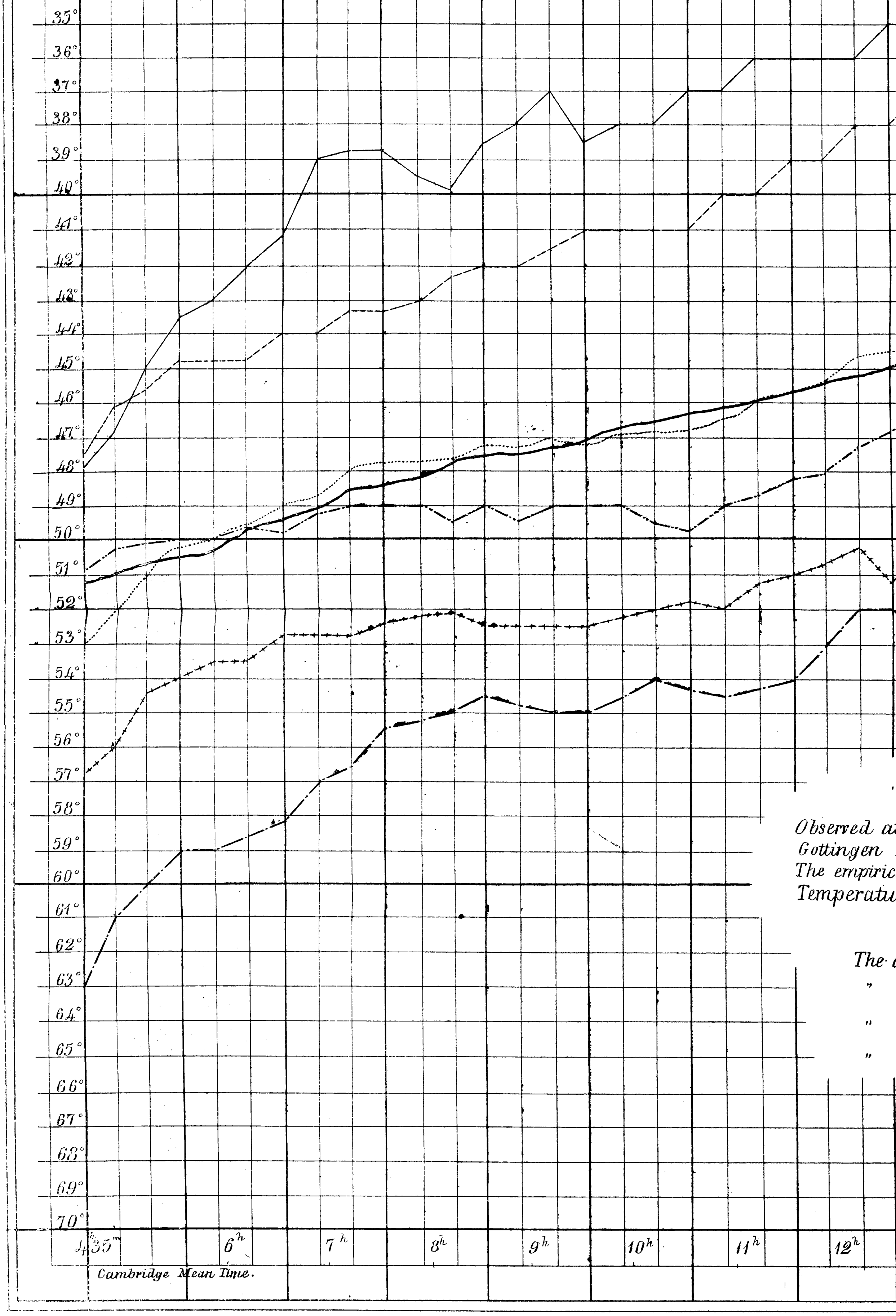
…mperature $= 47°7 - 3°8 \sin.(t - 14^h 21^m 44^s) - 0°8 \sin 2 (t - 9^h 17^m 36^s) - 0°4 \sin.3 (t - 6^h 35^m 25^s) - 0°4 \sin.4 (t - 0^h 38^m 12$…

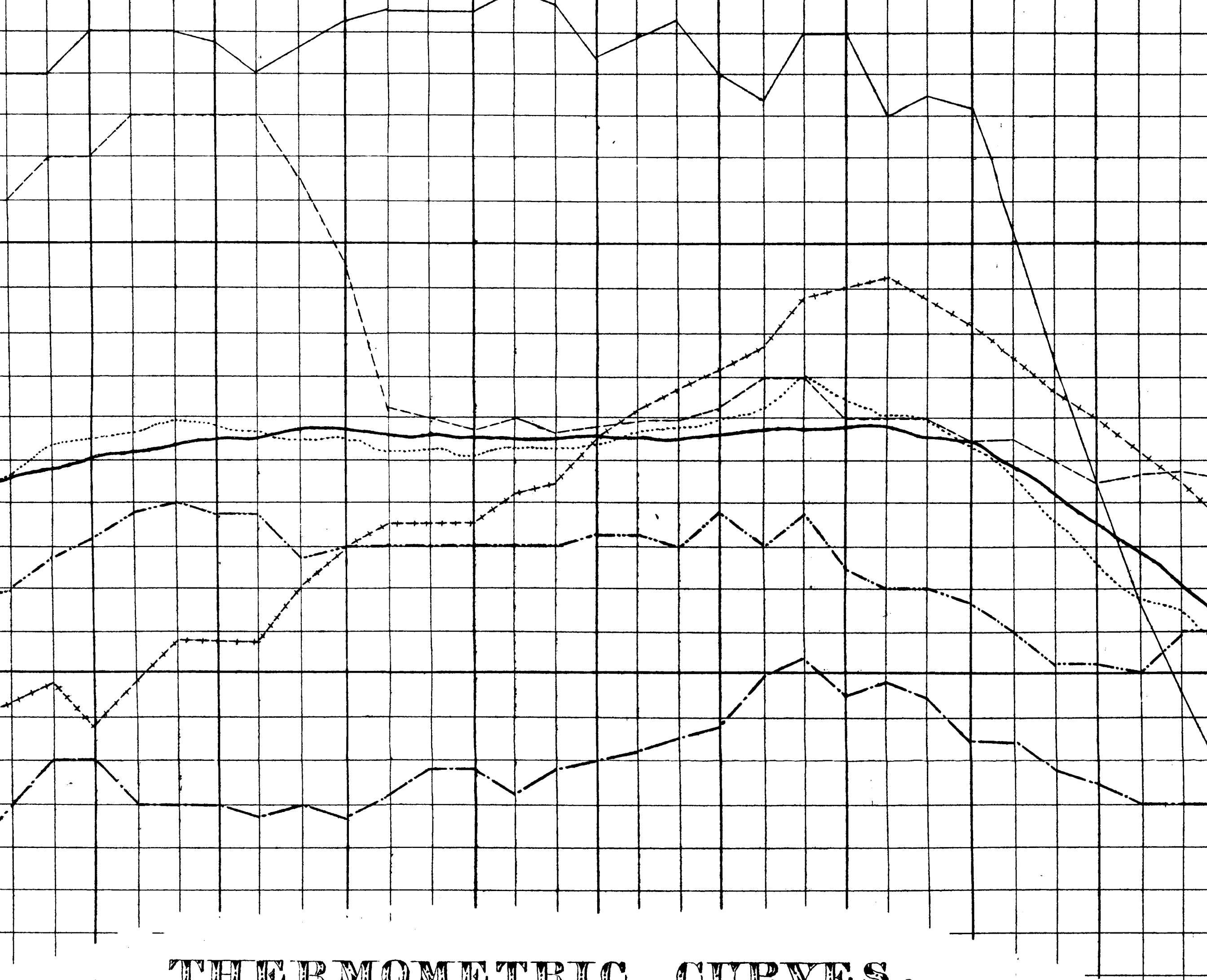
The curve from October $20^d 10^h$ to October $21^d 10^h$ is a line thus
" " " " 21 " " " 22 " " " " "
" " " " 22 " " " 23 " " " " "
" " " " 23 " " " 24 " " " " "
" " " " 24 " " " 25 " " " " "

The mean curve …

Pl. VI




35°
36°
37°
38°
39°
40°
41°
42°
43°
44°
45°
46°
47°
48°
49°
50°
51°
52°
53°
54°
55°
56°
57°
58°
59°
60°
61°
62°
63°
64°
65°
66°
67°
68°
69°
70°
35m
6h
7h
8h
9h
10h
11h
12h
Cambridge Mean Time.
Observed a
Gottingen
The empiric
Temperatu
The



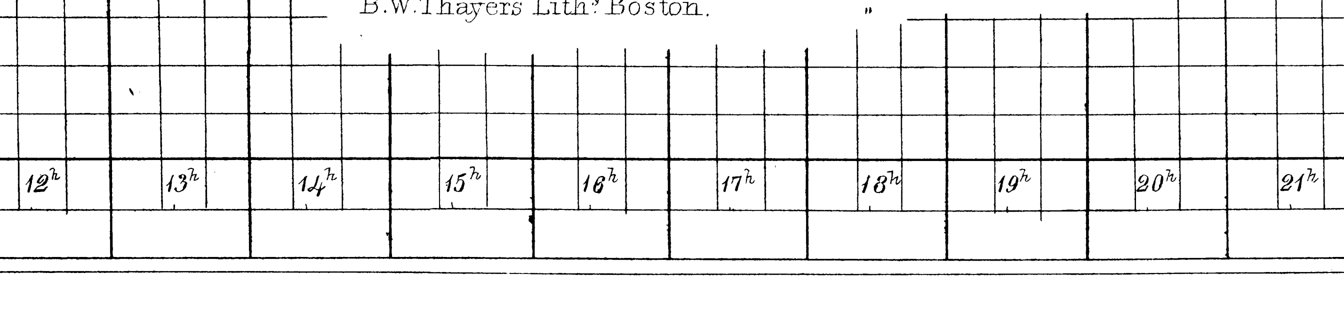
THERMOMETRIC CURVES,

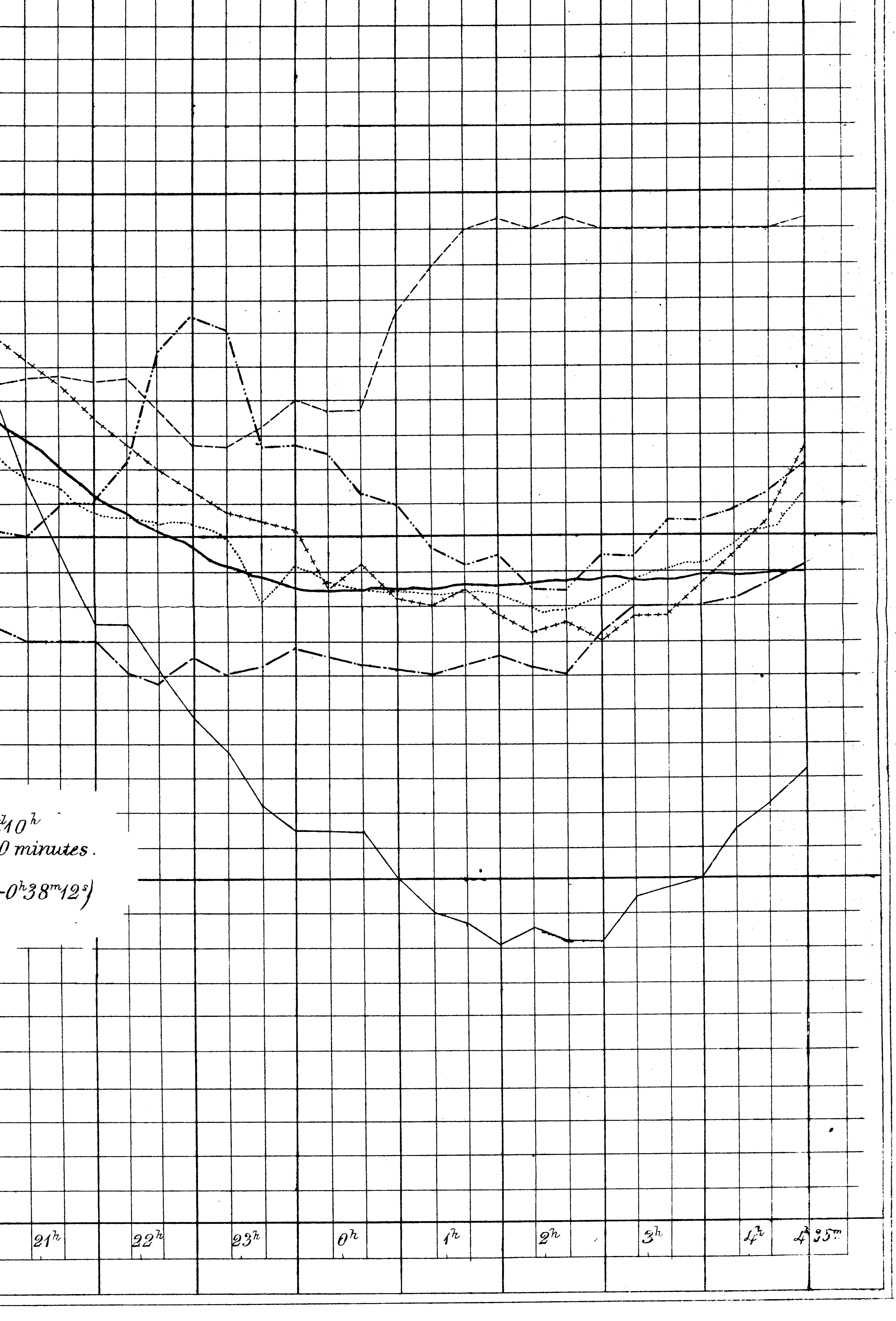
...served at the Observatory in Cambridge N.E. during the five days commencing 1840 October $20^d 10^h$ ...ttingen Mean Time, and ending October $25^d 10^h$. The observations were made at intervals of 20 minute... ...e empirical curve is calculated by the formula.

...mperature $= 47°7 - 3°8 \sin.(t - 14^h 21^m 44^s) - 0°8 \sin 2\,(t - 9^h 17^m 36^s) - 0°4 \sin.3\,(t - 6^h 35^m 25^s) - 0°4 \sin.4\,(t - 0^h 38^m 12$...

The curve from October $20^d 10^h$ to October $21^d 10^h$ is a line thus
" " " " 21 " " " 22 " " " " "
" " " 22 " " " 23 " " " " "
" " " " 23 " " " 24 " " " " "
" " " " 24 " " " 25 " " " " "
The mean curve " " " "
The empirical " " " " "

B.W. Thayers Lith.y Boston.





10^h
0 minutes.
-0^h38^m12^s)
21^h
22^h
23^h
0^h
1^h
2^h
3^h
4^h
4^h35^m